WELDING MANUAL TECHBOOK

GO FROM BEGINNER TO EXPERT

for welding professions.

SPECIAL SAFETY NOTE: For welding, we might use devices under high electric voltage, also most welding tools use flammable gases under pressure and all welding machines produce extremely high operating temperatures. Therefore incorrect handling of welding equipment can lead to burns and other serious or life-threatening injuries. This book is not intended as a beginner “do it yourself” guide and you can’t use this book to perform welding alone without expert supervision. Welding must be learned in welding schools and in the presence of authorized welding instructors because it is the best way to be sure that all the necessary measures for your safety have been taken properly.

Do not allow yourself sloppiness in any work, especially not the superficiality in welding jobs. I hope that this handbook will to some extent help you, today and in the future and that it will achieve its objective, which is to equip you for good welder.

The author will be grateful to every well-intentioned reader who points him to any errors or omissions in the pages that follow. I express special gratitude to anyone who suggests the way in which this book can be improved to be more valuable and useful in its next edition.

Somewhere in the world,

January 2017.

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Master of Mechanical Engineering

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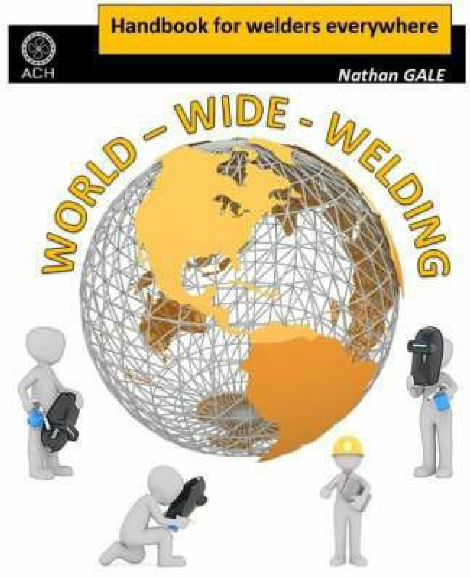


1.BASIC CONCEPTS IN WELDING

Definition of welding:
Welding is the process of joining welding material, mainly of metal or plastic, by the creation of a homogeneous compound.

Essentially, this is accomplished by melting (dissolving) the base material and adding the filler material in the form of a rod or wire, in order to create a „bath of molten material“ (weld pool) that cools and forms a strong bond. On the other hand, deposited filler material may have a higher hardness than the base material and thus, the socalled „weld on“, process or “hard facing” performs the protection of the workpiece.

In other words:
Welding is the process of making inseparable compound between the parts that are welded, by establishing an interatomic bond. During welding process we use alone or in combination, the heat and the calorific mechanical energy, and if necessary, additional material. The most frequently used welding methods in the field, are based on local warming of the material above the melting temperature when welded joint solidification occurs (eg. metal arc welding), or local warming of material to the melting point when a welded joint is formed with additional effect of pressure (eg. electric

resistance welding).

By Welding, it is possible to bond metal to metal, non-metals with nonmetals and metals with non-metals, but in practical terms, it means bonding metal to metal.

Welded joint is constructive unit, Fig. 1, consisting of a basic metal (1) and weld metal, weld or part, in which we have the face of the seam (2), the reverse side seam (3), the root of the weld (4) and the edge of the seam (8), Fig. 1.a. In welding procedures by melting, the welding seam is created during solidification of molten base metal and filler (additional) metal or base metal only. Part of the base metal, which melts in the welding process and enters into the composition of the weld metal, is called fusion zone (guard) (5), whose boundaries are marked with (6), Fig. 1a, with a depth (9), Fig. 1.b. Heat affected zone (HAZ), marked with (7) in Fig. 1a, is that part of the base metal, which is influenced by heating and cooling during welding, and therefore underwent some degree of structural changes, but below the temperature of melting. In FIG. 1 we can see the basic dimensions of the weld: the width (11), the thickness (12) and elevation (10), and that in the case of butt-joint, Fig. 1b, and fillet (corner) weld, Fig. 1c, as well as welded layers overlays, Fig. 1d, in which the thickness is important (13).

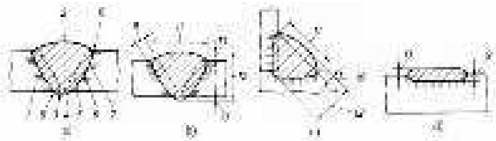


Figure 1. Welded joints - basic elements

Before welding, the edges of base metal should be prepared, resulting in a groove for welding, whose basic concepts are defined by standards, Fig. 2. The most commonly used grooves and their corresponding sutures (seams) are given in Table 1.

Prepared groove in fusion welding process can be fulfilled in one or multiple passes, or in multiple layers, Fig. 3, which depends primarily on the thickness of the base material. The weld is part of the metal seam, formed in a single pass or layer, Fig. 3.

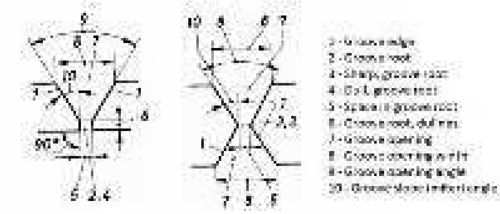
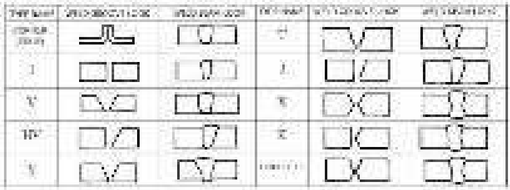


Figure 2. Basic elements of weld groove

Table 1. Shapes of the most weld grooves and corresponding sutures (seams)



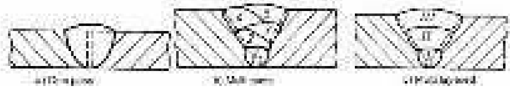


Figure 3. Types of seams

According to the shape of the seam face, there are several different types: flat, concave and convex seams, Fig. 4, and according to seam continuity they are divided into continuous, Fig. 5a and the broken dashed (spots), Fig. 5b, which may be symmetrical, Fig. 5c, or asymmetric, Fig. 5d.

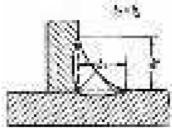
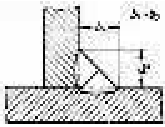

a) Convex

b) Concave

c) flat

Figure 4. Seam face - SHAPES

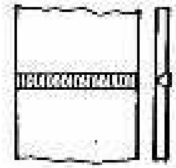
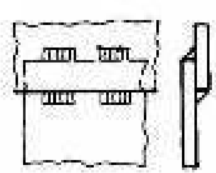
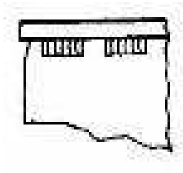
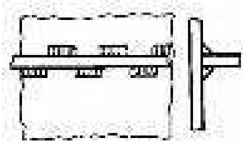
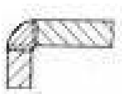
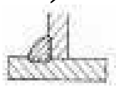
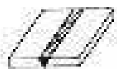
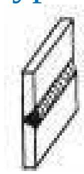
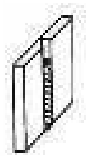
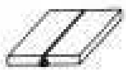

a) continual

c) symmetrical

b) dashed (spots)

d) asymmetric

Figure 5. Weld seams by continuity

Depending on the mutual position of the parts that are welded, the basic types of welding joints are a butt, folding, edge, T-joint, Fig. 6. But depending on the position, welding may be in the horizontal, vertical-horizontal, vertical and overhead position, Fig. 7. Welding positions that are not horizontal are called forced.

 a) butt  b) folding  c) edge  d) T joint Figure 6. Basic types of welded joints

 a) Horizontal   b) Vertical  horizontal

c) Vertical d) Overhead Figure 7. Welding positions

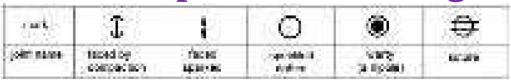
1.1 Labeling and presentation of the welds in the drawing

Drawing of welded structures must contain the information necessary for its development, such as a method of the groove preparation, geometrical dimensions of weld seam and welding technique. To represent these data as simply as possible, we defined the manner of presentation and marking of welds, consisting of a numerical and graphical label. Graphical mark defines the preparation of grooves and a seam forms, Tab. 2, the shape of the outer surface, Tab. 3, types of joints by welding pressure, Tab. 4, additional work on the root of the weld (fluting is marked with twin symbol in the form of the outer surface for asymmetric grooves or with two vertical bars in the middle of symmetrical grooves) and seam continuity for fusion welding (continuous seams are indicated by the horizontal line over the basic symbol).

Table 2. Tags of most used grooves and trademarks of their respective seams

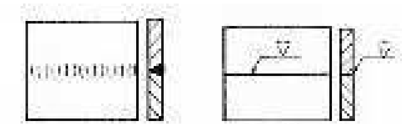
Table 3. Tags for the form of outer weld surface

Table 4. Codes for pressure welding

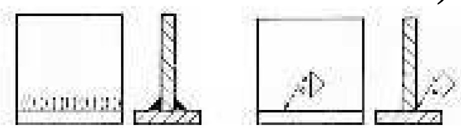


Graphical mark for a simplified representation of welded joints on the drawing is printed near the weld, on the fractured demonstration line or below it, Fig. 8. Thus, for example, designation in Fig. 8a defines the “V” Seam without surface treatment, the code in Fig. 8b continuous two-sided angled seam with a flat top, where “a” is the thickness of the seam (Fig. 4), and the tag in Fig. 8c intermittent two-sided asymmetric angular seam with a flat top, where “l” is the length of the individual seams (stitches), “e” is a distance between two stitches, “n” is a number of stitches and “a” is a thickness of the seam.

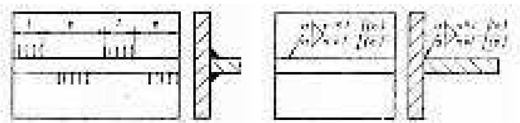
The numerical code contains the most important information depending on the type of joint compound, shape, and seam continuity, and it usually consists of two numbers separated by a hyphen, the first for the seam angle section, and the second for the seam length. Examples of labeling continuous joint compounds are given in Table 6 (Butt), presenting“I” joint, two-sided “X” joint compounds (symmetric and asymmetric), single-sided concave and double-sided symmetrical hollow straight joint. For intermittent compounds, there are presented the butt“I” and angle“T” junction. The complete code of the welded joint further contains a number of the welding procedure, according to data from the Tab. 5.



a) butt “V”



b) angular flat two-sided



c) intermittent asymmetric angular flat top

Figure 8. Examples of simplified presentation

of welds

Table 5. Classification of welding procedures 1 Arc welding 4

111 Coated electrode– E 41 (Shielded metal arc welding (SMAW))

114 Cored - Flux-cored arc 42
welding (FCAW)
12 Submerged arc welding 43
(SAW)
13 Soluble electrode wire with 44
shielding gas
131 Gas metal arc welding 45
(GMAW) – commonly termed MIG (metal, inert gas)
135 Metal active gas (MAG) 48
welding
14 Non-consumable electrode **7** in shielding gas
141 Gas tungsten arc welding 71
(GTAW) – also known as TIG (tungsten, inert gas)
15 Plasma arc welding (PAW) 72

185 Magnetic (magnetic (MPW)) rotating arc

bow 74

pulse welding

Welding in the solid state
Ultrasonic welding

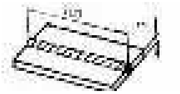
Friction welding
Forge welding (FOW)
Explosion welding
Diffusion bonding
Cold welding
Other welding processes
Aluminum thermal

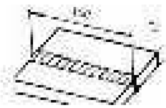
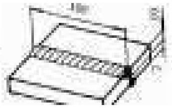
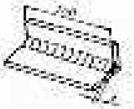
Electro slag welding (ESW)
Induction welding

2 Electric resistance welding 751 **(ERW)**
21 Spot (punctual) 76 22 Seam **91** 23 Projection welding 913 24 Flash welding (butt spark) 914 25 Upset welding 916 Laser beam welding

Electron beam welding **Brazing**
Furnace brazing

Dip brazing
Induction brazing
(UW)/resistance butt
welding

3 Gas welding 94 Soldering 311
Oxyacetylene welding **97 Braze welding**
Table 6. Examples of labeling continuous weld joints (compounds) sketch 

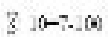



Description
Label (mark)

unilateral "I"

joint, thickness
3 mm, the length
of suture 100
mm
symmetric "X"

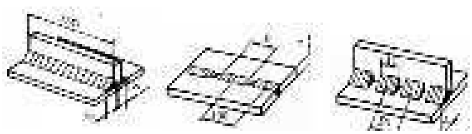
joint, thickness

15 mm, the
length of suture
100 mm
Unbalanced

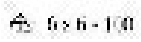


(asymmetric)
"X" joint,
thickness 17 mm
(first weld 10
mm, the second
7 mm), the
length of
seam 100 mm
Recessed

(concave) joint,
cross-section 4
mm, seam length
100 mm



symmetrical flat



level "T"
junction, a
length of the legs
6 mm, seam
length 100 mm
butt "I" joint

(compound), 5
mm thick, 3
welds length of
10 mm, step 100
mm
angle level "T"

junction, section
4 mm, 4 welds
length of 10 mm,
step 50 mm

2. WELDING PROCEDURES

Today it is considered that at least the 98 welding procedures are mastered and applied in practice, including soldering, as defined in ISO 4063 (EN 24063). Welding procedures can be divided into methods by melting and pressing processes, in which the first group includes those operations in which the fusion process takes place by melting and solidification of the joint connection, and the other group includes methods in which the joining process takes place without melting. Beside this, welding processes are often divided by source of energy: electric (arc, resistance, beam), chemical (fire, explosives, thermite welding), mechanical (pressure, traction, ultrasound) and other (eg, light).

2.1. Gas welding

(311)

Gas welding is the process of connecting metal parts by melting and solidification of primary and (if necessary) of additional metal with the flame produced from combustion of the fuel gas.
The most commonly used fuel gases are based on hydrocarbons: methane (CH_4), methylacetylene-propadiene (C_3H_4 - trade name MAPP), acetylene (C_2H_2), propane (C_3H_8), propylene (C_3H_6), butane (C_4H_{10}) and hydrogen (H_2). The amount of heat liberated from combustion, as well as the highest temperature of the flame, depend on the type of combustible gas. It is understood that the fuel gases burn in a stream of oxygen, if not stated otherwise (eg. Combustion in the air). In order to achieve combustion in a stream of oxygen, combustible gas and oxygen from the Special pressure vessels - a bottle (or some other way) are brought to the burner, where they are mixed and exits in the appropriate proportion. Thus is provided the

combustion of the fuel gas on top of the burner, which together with the torch, bottles for gas storage and supply gas hoses, as well as auxiliary and additional devices (eg. reduction valves), makes gas welding equipment.

Table 7. Max. flame temperature of commonly used gases

Acetylen e Propane Butane Methane propylene MAPP hydrogen t_{max} (°C) 3087 2526 2300 2538 2865 2927 2655
(F) 5588.6 4578.8 4172 4600,4 5189 5300,6 4811

2.1.1. Apparatus for welding

Apparatus for gas welding consists from:

1. Oxygen and acetylene bottles
2. Reducing valves
3. Inlet hoses
4. Torch with variable nozzle
5. Extra additional tools

Bottles for technical gases fall in the category of pressure vessels and are subject to the appropriate standard. Bottles oxygen have a capacity of 40 liters, in which it is possible to store 6 Nm3 (normal 6 meters cubic) at a pressure of 150 bar and a temperature of 20 °C (68F). If it is assumed that the oxygen in these conditions behaves like an ideal gas, it is possible on the basis of the pressure in the tank to calculate the amount of gas remaining in the bottle (eg. if the tank pressure is 120 bar, the remaining amount of Oxygen is 120x40 = 4800 l). Oxygen bottle is colored blue or has a blue strip on 2/3 of height. Bottle of acetylene is painted white or has a white strip on the 2/3 height. Acetylene in a bottle dissolves in acetone because acetylene as unsaturated hydrocarbon is very explosive at elevated pressure. In addition, the bottles are pre-filled with a porous mass of (mostly wooden charcoal or a mixture of coal and diatomaceous earth - kieselguhr). The acetone flows in this porous mass and then dissolves acetylene. The resulting mixture may be subjected to a pressure of 15 bar.

Bottles of acetylene and oxygen may be

handled only by qualified personnel, ie. a person who holds a certificate for handling pressurized bottles. Errors when handling bottles with technical gases under pressure are the most common cause of the accident with very serious consequences.

Therefore, when handling this kind of apparatus the following recommendations should be respected:

- Regularly check whether the bottles have gas leaks smearing with soapy water, not fire.
- If the cylinder valve yields even after tightening, this bottle should be removed from service and kept away from the fire, electric motors and other sources of heat and sparks.
- Each valve repair, fixing any fault and overhaul should be left to authorized persons. When working with the bottles, they must be in a vertical position or at an angle of 45°, thus preventing leakage of acetone.
- The residual pressure in the bottle depending on the ambient temperature should be 0.5 bar (T <0°C; T<32F), 1 bar (0 <t

<5°C; 32<t< 41F), 2 bar (15<t <25°C; 59<t<77F) or 3 bar (25<t <35°C; 77<t<95F) in order not to excessively increase the loss of acetone from a bottle (for the aforementioned pressure, bottle is considered to be empty).

- The valve on the bottle of acetylene may be opened only with a special key.
- If the bottles were at a temperature below 10°C (50F), they must be brought in a room where the temperature is normal, two hours prior to use.
- Bottles are not allowed to overheat, as the pressure increases significantly.
- The bottle valves should be opened slowly in order to avoid gas pressure bumps in the terminal devices.
- Particular attention should be paid not to handle a bottle of oxygen with greasy hands, gloves or tools (in the presence of oxygen, grease will start a fire). As the working pressure is considerably lower than the pressure in the bottle, the bottle is necessary to be supplied with reduction valves for oxygen and acetylene, etc. Figure 9. Both reducing valves have two pressure gauges, one for the pressure in the bottle, the other for

operating pressure. The operation principle of regulation valves is the same, and the only constructive difference is in the connection to the bottle - with oxygen binding is over nuts, but with acetylene, it is over stirrups - which excludes the possibility of incorrect binding. Besides that, the difference is in the scope of measurement - with oxygen gauges are up to 300 bar (pressure in the bottle), or 16 bar (working pressure), and for acetylene up to 40 bar, and 2.5 bar working pressure.

Special attention should be paid to the handling with reduction valve for oxygen. As the contact of oxygen with grease, oil or similar material can cause an explosive ignition, it is forbidden to handle reducing valve for oxygen with greasy or dirty gloves. Also, this valve is characterized by the appearance of icing due to the pressure difference at the entry and exit and a corresponding drop in temperature. In order to prevent this, as pure as possible oxygen gas should be used, a heater should be attached before the valve or a two-stage pressure reduction valve should be installed.

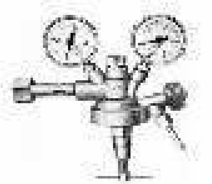
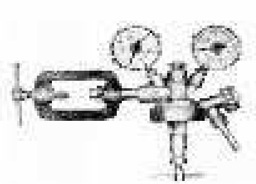
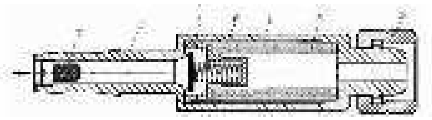
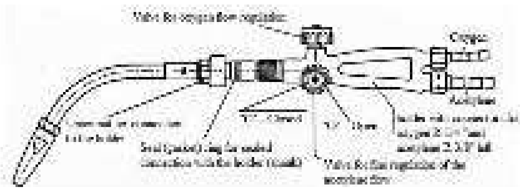

a) For oxygen

b) For acetylene

Figure 9 . Reduction valves

Beside the reducing valves, so-called dry valves are also used, and they are placed between the reduction valve and the burner, FIG. 10. The principle of the dry valve operation is as follows: through rubber hose flows the gas to the pipe socket extension (2) of the valve and opens the non-return valve (4), flows through the porous cartridge in the interior of the valve (5), then through its porous wall in the middle of a cartridge, and hence to the extension (3) and into the burner. In the case of explosion, kickback flame reaches the chamber between the wall of the valve stem (1) and the cartridge (5) and there, the flame goes out, because when passing through the porous tray flame cools below mixture of gases ignition temperature. The increased pressure of the explosion almost momentarily closes the check valve.

 Figure 10. Schematic of dry valve

Inside the burners, a necessary mixture of oxygen and acetylene is created. During this process, it is required to obtain the stable flame of a certain shape and thermal power. The main parts of the burner are shown in Fig. 11. There are many types of burners in use, that are divided according to the supply pressure (low and high-pressure burners) and the gas flow regulation (constant and multiple flow burner).

 Figure 11. Burner - schematic representation

According to the feed pressure, the burners are divided on the basis of the gas mixture pressure in the nozzle and pressure of each of the gases (oxygen and acetylene). If the mixture of gases pressure is less than the pressure of gases then it is a low-pressure burner, and if the pressure of the mixture is greater than the pressure of at least one gas, then it is a high-pressure burner.

According to the regulation of the gas flow the burners are classified as those in which the flow change is possible in very small limits (constant flow burner - without tube change), and those in which the regulation is possible, usually by changing the pressure feeding power (multiple flow burner - with changing tubes).

In addition to properties, burners differ in jets sizes, which are selected in relation to the thickness of the base material. According to this division, burners are marked with numbers 1 to 8 and selected depending on the thickness of the base material.

When handling burners, you should take into account the following: ▪

Repairs of the burner should only be operated by qualified personnel;

- Nozzles must be cleaned with the special needles provided by the manufacturer;

- The special brushes must be used, for periodical cleaning of the injectors.

- When replacing a pipe, castellated nut should be well fastened, because a weak seal will produce kickback flame;

- The flame lights up so that the first oxygen is released a little, and then acetylene; only when mixture is ignited, the flame can be regulated (it turns off in reverse order);

- When the burner is "whistling", this means that the flame is burning at the injector instead of at the nozzle; supply gas should quickly shut down; if the burner is too warm, it should be cooled;

In Tab. 8 the most common faults of the burners are listed, their causes and ways of eliminating it.

Table 8. The most common faults of burners operation **Malfunction**

The flame will not start
Flame skewed or sideways
The flame away from the nozzle

The flame occasionally increased unstable,

Backfire and cracking

Flame "whistling" and burning inside (Usually after return shock)

Cause of malfunction

- Tufted nut is not tight properly
- Valve clogged
- Nozzle partly clogged
- Too much pressure oxygen
- Too much pressure acetylene
- Water in a rubber hose
- Reduction valve froze

- Nozzles are heated during operation
- Too low pressure oxygen
- The nozzle is too close to the subject
- Burner is not sealed properly
- Nozzle and pipe overheated
- Dirty nozzle
- Damaged hole in the nozzle

Fixing the malfunction

- Tighten the nut
- Clean the valve
- clean nozzle

- Regulate valves on the burner or reduction valve

- Water squeeze
- Thawed reduction valve

- Cool the burner in water
- Increase pressure
- Move away nozzle 3 ÷ 5 mm
- Tighten the pipe at the junction

- Cool the torch
- Clean the nozzle

- Change the nozzle

2.1.2 Procedure application

The main advantage of gas welding is the welder ability to control the speed of the heat introduction, control of the temperature in the welding zone and weld metal oxidation. Also, the shape and size of the weld can be better controlled because the additional metal is introduced regardless of the source of heat. The advantages of the gas welding process also include the low cost of equipment, its mobility and relatively easy handling.

On the other hand, the amount and concentration of heat are lower than in other welding processes, so it is characteristic for gas welding to have long periods of warming and cooling, and therefore the structural changes in the HAZ (heat affected zone) are more pronounced and less favorable. Consequently, this process is suitable only for welding the thin metal sheets and tubes, in particular of smaller diameter, as well as for their repair welding. Flame of gas welding is also used for cutting, brazing, surfacing, preheating, heat treatment and easier shaping operations, such as bending and correction.

Depending on the ratio of acetylene and oxygen, we have different flames: 1) reducing flame (lack of oxygen); 2) neutral flame (complete combustion) and 3) oxidizing flame (excess oxygen). Although theoretically, mixtures of oxygen and acetylene flame at a neutral level is 1:1, in practice, under a neutral flame we include mixtures of O_2: C_2H_2 = (1,1 ÷ 1,2): 1. The excess oxygen is consumed for the combustion of the surrounding gases. At a neutral flame, there are visible three different zones, Fig. 12:

· The inner cone or core in shape of the cone or cylinder (depending on the flow mode of gases), in which part of the primary combustion takes place. While it burns a small part of the mixture of gases, the most of the mixture is decomposed into carbon and hydrogen. The released amount of heat warms the free carbon, creating a bright layer core, which gives the impression of a bright white color.

· Central (middle) zone, wedge-shaped, where the rest of the primary combustion takes place, and secondary combustion starts (it means starting the oxidation of 2CO and H2 with the oxygen from the air). In this zone, the highest flame temperature is reached up to 3100°C (5612F), Fig. 12a, in 4 ÷ 6 mm from the top of the core, and it is used for welding. Therefore, the intermediate zone is also called the zone of welding.

· The outer envelope or shell (wrap) of flame, in which the secondary combustion takes place at the expense of oxygen from the air. The temperature in the secondary combustion zone is much lower than the maximum, the flame color in this zone goes from blue-purple in the middle to yellow-orange at the ends.

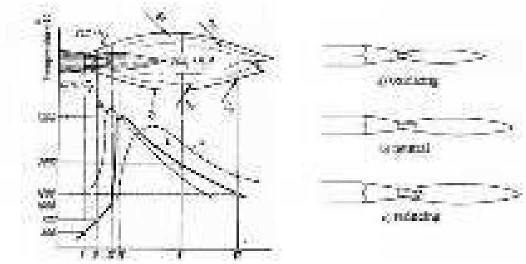


Figure 12. A schematic layout of the flame (a - oxidizing b - Neutral c reducing)

Therefore, it is very important to maintain a prescribed distance between the core and the surface of the workpiece (3 ÷ 5 mm), because otherwise following errors arise:

- If the core is too (anodizing) hard layer; close to the molten metal it will create oxidized

- If the core is too far away, welding dispersal is difficult, and the occurrence of the gas bubble is frequent.

A neutral flame is used for welding steel, copper, nickel, and its alloys, bronze and lead. Reducing flame is applied when requesting an increase of carbon in the weld eg. For welding cast iron, and for welding of aluminum and aluminum alloys, magnesium alloys and welding hard alloy. Oxidizing flame is avoided, because the Oxygen reaction has a very detrimental effect on the properties of the alloy, except for welding brass in which the excess of oxygen is used to prevent evaporation of zinc. Flame temperature with excess oxygen is higher than other types of flames because of reaction from the combustion of metal or other present elements, so the oxidizing flame is used sometimes to increase the steel welding productivity, which as a rule makes the metal weld seam with oxide error type.

Based on the flow out rate, we have: soft flame (50 ÷ 80 m/s) and hard flame (120 ÷ 180m/s), depending on the pressure and flow of gases. Soft flame is unstable and sensitive to the appearance of flashbacks and is used for welding stainless steels, easily soluble metals (Pb, Zn) and soldering. Hard flame is difficult to control, and it is common to produce the deflation of molten metal from the metal bath. Therefore, in practice most often used flame is with flow speed ranging from 80 ÷ 120 m/s.

Oxygen allows burning of combustible gases, and is located in the air (21% by volume share). At 15°C (59F) and at atmospheric pressure, oxygen density is 1.43 kg/m3, molar mass 32 g/mol, and in the liquid state it passes at
-183°C (-297.4F). In the gaseous phase, oxygen has no color and odor, it is non-flammable and explosive. However, since in his presence some substances become flammable, handling oxygen must be dealt with great care.

Oxygen is most commonly produced by fractional distillation of liquefied air. Technical oxygen has the purity of 99.2 to 99.8%, and impurities are nitrogen, argon, and water. The purity of oxygen is essential for its use. Oxygen is transferred and stored in steel containers under pressure 150-200 bar.

Acetylene is a flammable gas without color, it has a characteristic odor, it is non-toxic and it

is water-soluble in the ratio of 1:1 and in acetone - solution in the 1:25 ratio (at room temperature and atmospheric pressure). The solubility of acetylene in acetone increases with pressure and decreases with increasing temperature.
Acetylene is highly explosive in the presence of oxygen or air. Acetylene is transported and kept in the steel containers at the pressure of 15 bar, and in the case of high consumption it is more rational to use acetylene developers.
To obtain acetylene, we also use pyrolysis processes of hydrocarbons and partial combustion of methane in oxygen.

2.1.3 Additional materials and fluxes

Additional materials are delivered in the form of wires and rods. In the case of welding low carbon and low alloyed steel filler material is in the form of a rod length of 1000 mm or Wire coils weight 40kg, standard diameter: 2; 2.5; 3.25; 4; 5; 6.3 mm. Identification of additional material can differ from

countrY to country (even between factories), but usually, it consists of two parts: the general (the letter P) and supplemental (letter O, Z, Y, or the digits 1 to 6) with the meaning given in Table 9. Wires are copper-coated to protect against corrosion. Manufacturers most often have their own tags for wire composition, mechanical properties, and application.

Table 9. Wire identification for gas welding of steels

Symbol	Z	Y	1	2	3	4	5	6
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	

Table 10. The wires for gas welding of steels

[illegible] [MPa]	[illegible] [%]	[illegible] [J]	[illegible] [%]					[illegible]
			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			[illegible]
410-470	16-22	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Fluxes in form of powder or paste are used for welding cast iron, non-ferrous metals and alloys, stainless steel and other alloys. The main reason for applying flux is refractory oxides, which are formed by welding the abovementioned materials and their presence prevents successful welding. By applying flux on the extra or on the basic material we achieve a dual effect preventing to some extent the oxidation of the liquid metal, on the one hand, and lowering the oxide melting temperature, on the other hand, thus ensuring their removal in the form of slag.

Fluxes are classified according to the chemical composition on the acid and base ones. The most commonly used are acid fluxes on the basis of boron, such as boric acid, H3BO3 (preferably for welding copper and its alloys), or borax (Sodium borate decahydrate- Na2B4O7 10H2O), which easily breaks down oxides of other metals (e.g., Cu, Zn, Mn), and basic fluxes such as sodium carbonate, Na2CO3, and potassium carbonate K2CO3, (primarily for gray cast iron).

2.1.4 Gas welding technology

Determining regulations of gas welding technology, involves choice and inclination of the burner, selection of welding wire, as well as a selection of techniques and welding parameters (flow rate, the diameter of the wire, welding speed, consumption of acetylene, oxygen, and welding wire).

The size and strength of the burner are chosen based on the type and thickness of the base material. Burner strength is measured by the flow of acetylene (l/h). The position of a burner (torch) significantly affects the efficiency level of flame heat, as well the protection of the melt. Utilization of heat is greatest when holding the torch perpendicular to the welding site Fig. 13. This position of a burner provides deeper and narrower welds, and it gives better results with thicker materials, and better protection of a melt. Variance in a burner position from perpendicular, gives much shallower and wider welds, which is favorable for welding thin materials. With gas welding commonly used angles of a burner are 60 ÷ 80°, except in very thin sheets, where lower slopes are used, 45 ÷ 60°, Fig. 13.

The type and diameter of the wire are chosen depending on the base material and its thickness. During this we should bear in mind the requirement for the wire to melt at optimum speed, not too fast nor too slow compared to the melting of the base material. When welding copper, aluminum and their alloys, the wire is melting faster than welding steel, therefore burners with greater strength are used. From this, it follows that diameter of the welding wire in relation to the thickness of the base material should be larger than in steel welding.

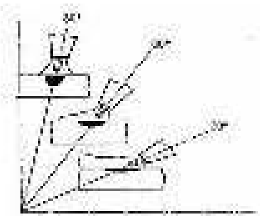
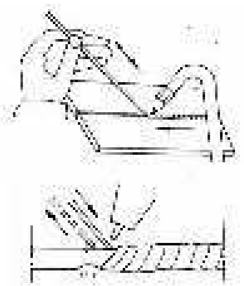
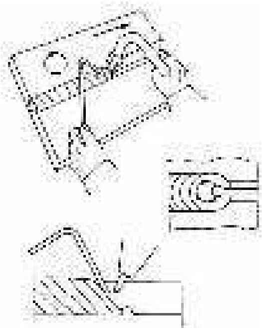


Figure 13. The effect of the slope of the burner to welds forms



a) Forward



b) Backward

Figure 14. Techniques of gas welding

Depending on the movement of the torch (burner) and wire there are two gas welding techniques: forward and backward (in the sense of the mutual position of the wire and torch), Fig. 14. These two techniques are also called the left and the right, this is an appropriate name only if the burner is held in the right hand.

Forward welding technique is based on the following, Fig. 14a:

• The flame is directed toward the edges of the base metal (groove).

• The wire is held in front of the flame, her top is near the place of welding, occasionally it dives into the metal bath and should be into flame protection.

• The movement and the angle of the wire and the burner depend on the welding position and the thickness of the base metal. In the case of butt “I” joint on a thin sheet (up to 3 mm), wires are moved without transverse oscillation, and the torch moves from one end of the groove to the other opposite end of the groove, with transverse (“zig-zag”) or circular motion, while their slopes are around 45°.

Backward welding technique comprises the following Fig. 14b. :

• The flame is directed towards the metal bath and evenly heats and melts the basic and additional material.
• The wire is kept behind the flame and is located between the base metal and the torch. Top of the wire is constantly immersed in the melt, and it moves in a circle and constantly mixes the melt.

• The way the wire and the torch are

conducted and angled also depend on the position of the welding and thickness of base metal. In the case of butt “V” joint in the sheet with thickness more than 3 mm, the wire is inclined at 45° and moving in the circle, from edge to edge of the groove. The torch is inclined at 45-70°, depending on thickness, and it moves in a straight line. The welding forward technique is simpler to operate, control of metal bath is easier and nicer and smoother welds are created. The backward welding technique has better heat utilization and better metal bath protection. Forward welding is slower, and consumption of acetylene is growing much faster with increasing width, than with backward welding. If thicker materials are welded with forward technique, it is difficult to achieve uniform root weld (usually drops dripping occur), and also the potential for oxide inclusions are increased. Therefore, the forward welding technique is limited to a thickness up to 5 mm, and for the larger thickness the backward welding technique is used, because its benefits then come to the fore. On the other hand, if bearing in mind the fact that the gas process practically is not used for pieces of greater thickness, it is clear that the back welding technique is applied very rarely, for example in some variants of welding pipes.

2.1.5 The selection of welding parameters

Guidelines for selecting the basic parameters for steel welding with forward technique (horizontal position, angle - corner and butt joint, including variant without additional metal) and for welding steel with the back technique are given in Table 11. Data on consumption of gas and wire and welding time are given in relation to 1m (1meter = 3,28ft) of the weld.

Table 11. The parameters for gas welding of steel plates Sheet Tip DiameterWeldingWelding Acetylene Oxygen consumpt thickness(Jet) of wire time speed consumptionconsumption of wire [mm] Siz e [mm] [min] [m/h] [liters] [liters] [gram]

[-]
Horizontal butt connection - welding forward techniques 1 1 2 5 12 8.5 10 20 2 2 3 10 6 35 42 50 3 3 3 15 4 75 90 90 Horizontal angle corner connection - welding forward techniques 1 1 2 6 10 12 14 25 2 2 3 10 6 42 50 48 4 3 4 20 3 160 210 200 6 4 4 30 2 375 450 440 10 6 5 50 1.2 1000 1200 1100 Horizontal butt connection - welding techniques forward - without additiona metal

1,0 1 - 3 20 5 6 -
1,5 2 - 4,30 14 11 13 -
2,0 2 - 5 12 18 22 - Horizontal butt connection - back welding technique 5 4 3 20 3 165 198 206 6 4 3 24 2,5 240 288 290 8 5 4 32 1,85 486 580 580
10 6 5 40 1,5 665 800 800
15 7 6 60 1,0 1500 1800 1800

2.1.6 Adjusting the flame of acetylene

Burners for welding:


Figure 15. The burning

of acetylene in the air is not suitable for welding.


Figure 16. Reducing flame, metal weld seam boiling and not clean.


Figure 17. A neutral flame, suitable for most welding.


Figure 18. Oxidation flame, weld metal seam foams, sparks, and burns

Burners for heating:

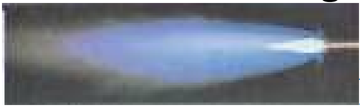


Figure 19. Reducing flame, not recommended for fast heating


Figure 20. The neutral flame, the most commonly used.

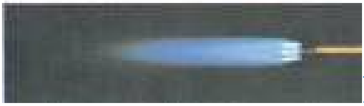


Figure 21. Oxidation flame, not recommended.

Burners for cutting:


Figure 22. Reducing flame with the flow of oxygen (for cutting), suitable for cutting cast iron


Figure 23. A neutral flame with flow oxygen (for cutting), suitable for steel


Figure 24. A neutral flame without oxygen (for cutting), set to cut steel


Figure 25. Oxidation flame with the flow of oxygen (for cut), not recommended

2.1.7 Adjusting the flame for cutting with MAPP gas

One-piece nozzles:

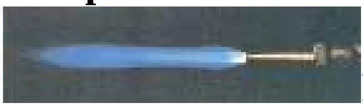


Figure 26. Reducing flame


Figure 27. The neutral flame, for machine cutting

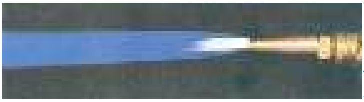


Figure 28. Poor oxidative flame, for manual (hand) cutting and for cutting that must start quickly and for making bevel cuts


Figure 29. Oxidation flame for preheating, not recommended for cutting

Two-piece nozzles:


Figure 30. Reducing flame for preheating


Figure 31. The neutral flame for preheating, for machine cutting

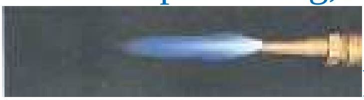


Figure 32. Oxidation flame for preheating

Models of the stars to set MAPP gas:

Keep the nozzle straight up the sheet without the involvement of oxygen for cutting. This method is not used for acetylene.

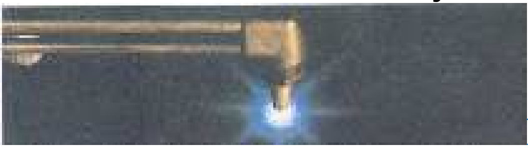


Figure 33. The neutral flame for preheating, for cutting

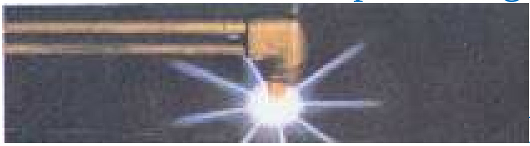


Figure 34. Very weak oxidizing flame

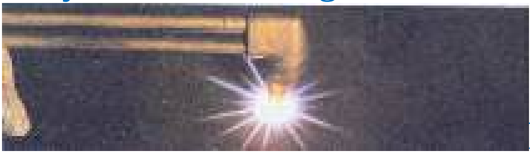
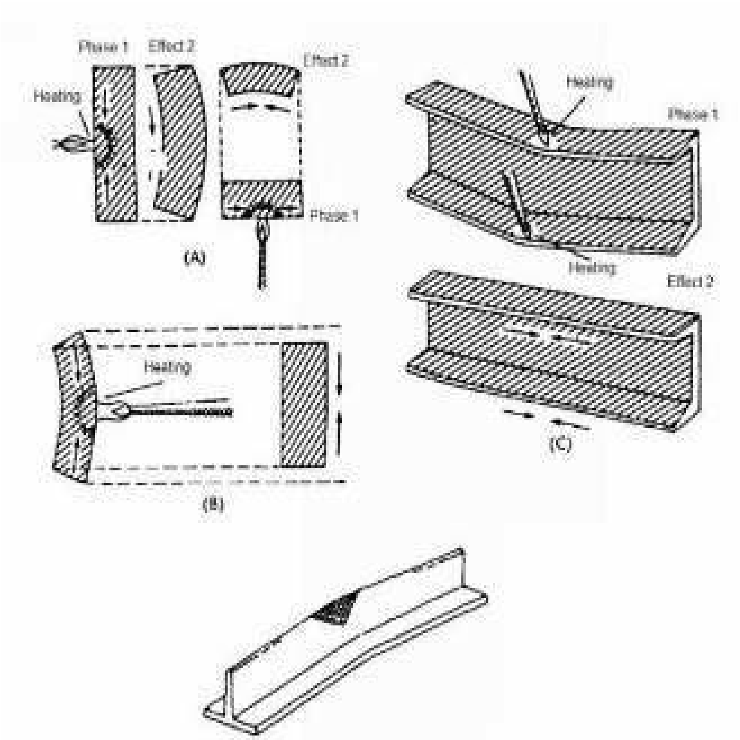


Figure 35. Poor oxidative flame, preheat for drilling holes

2.2 SPECIAL GAS-FLAME PROCEDURES

Under special gas-flame processes means

flame cleaning, flame straightening, welding under gas pressure and preheating. Some aspects and applications of the above methods are presented in Fig. 36 and 37.



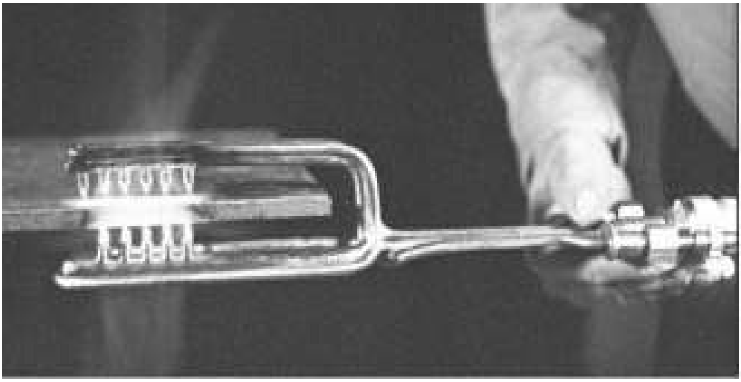
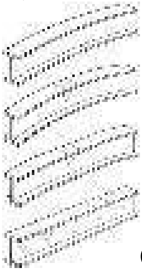


Figure 36. Effect of flame on the plates and profiles

a)

b)



c)

d)

Figure 37. Correcting (straightening) long profile

An example of correcting thermally deformed welded joint is shown in Fig. 37, where correcting of a long“I” profile is shown, bent around a horizontal axis as a result of longitudinal welding of vertical and horizontal sides, Fig. 37a. To correct such a bent profile, the middle part must be warmed up quickly (shaded area, Fig. 37b) to a temperature of red boiling glow, and then cooled in air, after which the part of the profile will be straightened, etc. 37c. In order the whole profile to be corrected, it is necessary to repeat the cycle of warming and cooling on a sufficient number of adequate places (positions of the piece) Fig. 37d.

2.3 Manual metal arc welding (MMA or MMAW) PROCEDURE with Covered electrodes (111) or Shielded

metal arc welding (SMAW)

Manual metal arc welding with coated electrode is a method of joining metals by melting of coated electrodes and a part of the base metal in an electric arc that is established and maintained between the workpiece (base metal) and the electrodes, Fig. 38. The melting of electrode core provides additional material to fill the groove, and melting, combustion and evaporation of lining (shield) provide the protection of metal bath from the surrounding gases and air. The molten cladding ingredients are mixed with the molten metal before they float to the surface because they have a lower density than the metal bath, and before they harden in the form of slag. The slag protects the metal weld from environmental influence and slows the cooling and after welding it is removed with a hammer.

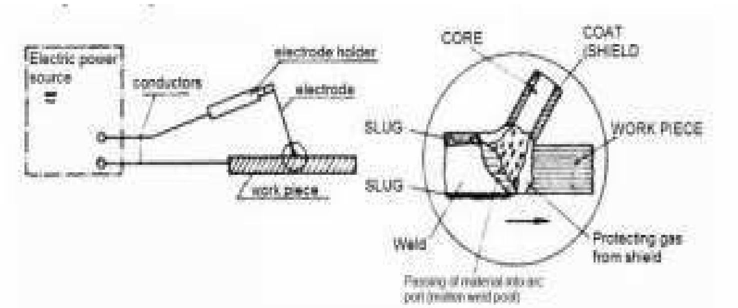


Figure 38. Schematic representation of MMA welding

2.3.1 Application procedure

Due to the easy handling and relatively low prices of devices and additional material on the one hand, and a good quality of a compound, On the other hand, manual metal arc welding with coated electrode, has been done more often than all other methods combined. For its wide usage, even more, contributes the fact that the restrictions on the shape of objects and type of material to be welded, and restrictions of the welding positions, are lesser than all the others welding processes together. On the other hand, due to defects of MMA proceedings, in recent times more often are used other-arc processes. The main disadvantages of MMA procedure is the low productivity due to frequent replacement of electrodes and removal of slag (melting rate of additional metal is 1-2 kg / h), a complicated and timeconsuming training of welders, the impact man welders have to weld quality, bright light and harmful gases produced from combustion of the slag.

Manual meTal arc welding with coated electrode can be used for connection of a large number of conventional materials such as carbon steel, low-alloyed and high-alloyed steels, cast iron, copper, nickel, aluminum and their alloys. It is also possible to bond materials of different chemical composition, but if they are metallurgically compatible. This procedure is not applied for materials, which protection from lining gas products is insufficient, such as Ti, Zr, Cb, Ta, and Mo. Restrictions in the application in terms of thickness are more related to the economic and practical character, rather than to a process of welding with coated electrode by itself. The lower thickness limit can be set

from 2 mm, since with smaller thickness weld drops occur, which can be prevented by the special techniques of work, for example by the use of washers. The upper limit of the thickness can be set to 40 mm, as by the rule, over this thickness, it is not worth to use this procedure. However, in the case of nonstandard configuration, which significantly complicates the use of automated welding processes, the MMA procedure is recorded to be used for a thickness up to 250 mm.
One of the main advantages of the MMA process is that it can be used in all positions. Of course, we should not forget that the horizontal position is the easiest and should be used whenever possible, because it allows the use of large diameter electrodes and electric currents of greater strength, and therefore it allows the higher productivity of welding. In the case of forced positions for welding, we should pay attention to the choice of welding parameters and work technique.

Finally, a significant advantage in the

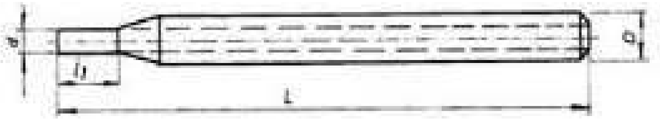
application of the MMA procedure is in its adaptability to the welding positions. In fact, it is relatively simple to reach inaccessible places such as large steel structures (bridges, buildings, plants, ships), pipelines and reservoirs, because it is enough to have long and flexible conductive cables and a power source independent of the city power grid networks.

2.3.2 Covered electrodes for MMA process

The electrode for MMA welding process has a metal core, which is all coated, except its free end, FIG. 39. The core of the coated electrodes as part of the circuitry transmits electricity (electrode free end is connected to a power source through the electrode holder), and also serves as an additional material. The main roles of the electrode wraps are:

- Protection of the welding zone from the surrounding oxygen, nitrogen, and hydrogen;
- Stabilization and ionization of electrical arc;

- Slowing the cooling of metal weld;
- Refining and alloying of the weld metal;
- Enabling welding in forced positions.



d - Diameter, l1 - free end, L - length, D - diameter of the lining Figure 39. Coated (covered or shielded) electrode

A welding protection zone of the surrounding harmful gases (primarily oxygen, hydrogen, and nitrogen) is made by gaseous and solid products of melting and coat liners combustion. This role of cladding (coat) is achieved multiply:

- A drop of molten filler material is protected by a slag which surrounds the drop, while it is in transition to a metal bath;
- A metal bath (pool) is protected by slag, which floats on its surface;

- Welding gases surround the place of welding and do not allow access of the surrounding harmful gases.

Stabilization and ionization of electric arc are achieved by adding sodium, barium, calcium and potassium in the lining, which produces gases with a great capacity for ionization, thus significantly increase the ability of air to conduct electricity.

Slag, formed from hardened parts of molten cladding covers the metal weld and slows its cooling because it has a much lower thermal conductivity. After welding, the slag is removed with a hammer.
To carry out deoxidation of metAl weld, the elements with high affinity to oxygen such as Ti, Al, Si, Mn are added to the wraps, in which the formed oxides are easily removed from the metal weld. Purification of other weld metal impurities is accomplished in a similar way as deoxidation. It is primarily based on the removal of hydrogen from the weld metal, for which serves CaF_2, then removal of phosphorus and sulfur, for which CaO and MnO are used, and removal of all other harmful elements, eg. nitrogen.
Alloying of the weld metal is needed to compensate the burnt share of certain

elements or to enhance the properties of the weld metal. For this purpose most often added are Mn, Si, and Ni.
The role of coverings (coats) in managing the forced position of welding (eg. Overhead) is obtained by increasing its viscosity (stickiness), which is achieved primarily by adding base and cellulosic ingredients.
According to the composition, the coating in the metallurgical sense can be acid, base, cellulose, and rutile, and recently more frequently used are mixed linings (coats) such as rutile-acidic, rutile-base and rutile-cellulose. The chemical composition and properties of these coatings are given in Table 12. Except to the above coatings, there are also special types of coverings.

Table 12. Chemical composition and characteristics of basic coating of steel electrodes Coating Chemical composition oxides of Fe and Mn, acidic aluminosilicates, manganese

rutile
rutile, aluminosilicates, ferroalloys

carbonates, fluorides, basic
oxides, hematite
cellulose fibers, rutile, cellulose silicates, deoxidizers

Properties
reduced viscosity of slag, beautiful appearance and bad mechanical properties of the weld metal beautiful appearance and good mechanical properties of the weld good mechanical properties of the weld, especially toughness (low content H) all positions, a high content of H, roots welded pipe
According to the comparison of the total diameter (including coating), D, and

core diameter, d, the electrodes are divided into thin coated (D / d <1.2), medium coated (1.2 <D / d <1.4) and thick coated (D / d> 1.4). On the transmission mode of additional metal during MMA welding process most affect have the thickness and type of lining and amperage. Increasing the thickness of the coating and adding the ingredients that reduce the surface voltage, will improve the transfer of droplets. Stronger currents also allow transfer from larger to tiny weld droplets, as it boosts the “pinch” effect and gases pressure.

2.3.2.1 Electrode Marking

To simplify identification of electrodes, standardized labeling is introduced, especially for certain types of construction materials, Table 13. Except to the above materials, there are also welding electrodes for other metals. Besides the standard labels of electrodes, we should always take into account the manufacturer’s labels. Tags, composition, mechanical properties, the basic characteristics, and application of electrodes are given in manufacturers catalogs. Electrode tags per EN standard are given to Fig.40, 41, 42 and 43.

Table 13. Standards for coated electrodes

EN Label	Purpose
EN 499	low carbon and low alloy steels and cast steel
prEN 1599	Creep resisting steels
prEN 1600	Stainless and high-alloyed steels

cast iron (gray iron, ductile iron, and malleable cast EN 499 iron)
On-welding on steel
prEN 757 HSLA (micro alloyed) steels of high strength

Figure 40. Marking of the electrodes for low alloyed steels

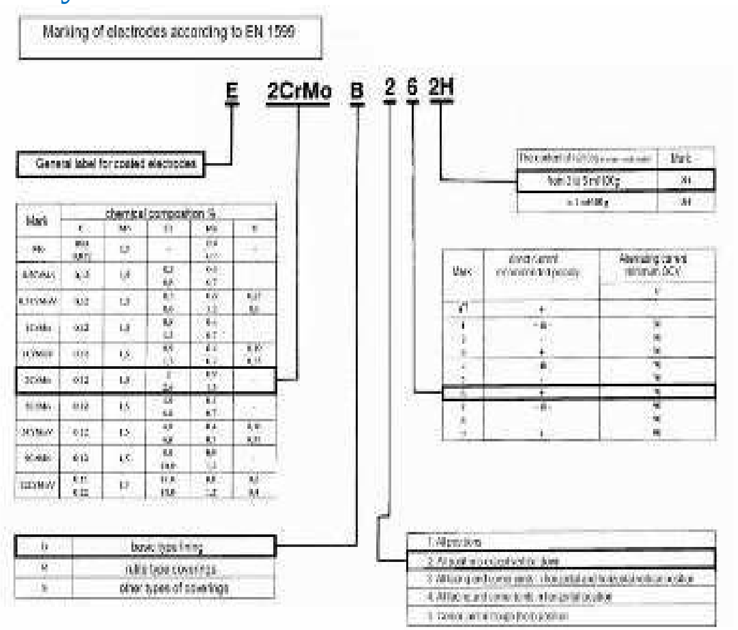


Figure 41. Marking of the electrodes for steels resistant to creep Figure 42. Marking of the electrodes for stainless and high alloyed steels

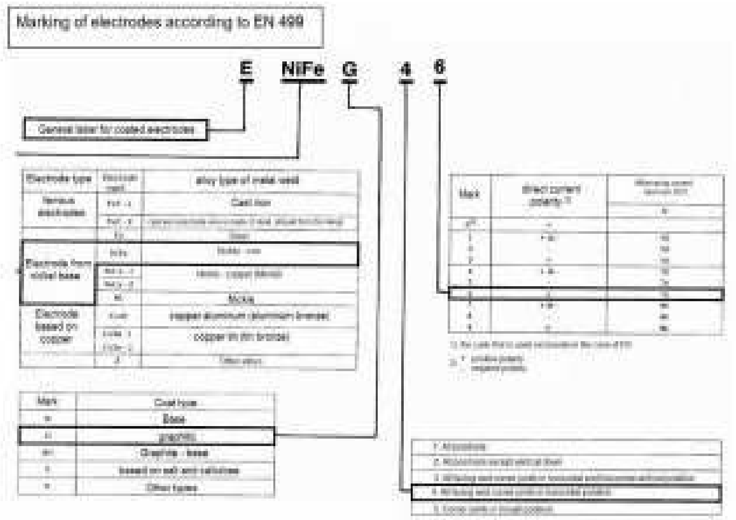


Figure 43. Marking of the electrodes for cast iron

2.3.2.2 Keeping and storage of electrodes

The manufacturer is obliged to pack electrodes in a way that they are protected against atmospheric influence. Each package of electrodes must be marked with information about the type, size and a number of batches as well as manufacturers sign (logo). These packets must be stored so that they are protected from atmospheric influence, especially from startup moisture, but they must also be ensured that there is no damage to the lining of electrodes and confusion of certain types of electrodes.

The electrodes that are well sealed in packages or in soldered tin boxes (prevented local presence of air) don’t need to dry afterward. Other electrodes before use should be dried, especially if it requires an increased quality of welded joints. This applies especially to base electrodes which are very hygroscopic. After 4 hours from box opening, some kind of basis electrodes can be considered damp and must be dried subsequently. The electrode drying is done in special ovens for drying with the possibility of temperature regulation. Beside this, every welder in the workplace should have a special cache oven-dryer for maintaining the temperature, usually between 60-900C, in order to prevent wetting of the electrodes during operation. The temperature and drying time depends on the type of electrode. Rutile and acid electrodes usually do not need to be dried, except in cases of noticeable signs of humidity. They should then be dried at a temperature of l200C for 2 hours.

Base cathodes disregarding great stockpiling much of the time should be dried, specifically, on the off chance that HSLA prepares are welded or thick plates of unmitigated steel. These cathodes are ordinarily dried at a temperature of 300 to 3500C for something like 2 hours. At a temperature 3500C, cathodes can be kept no longer than 10 hours, or if not it would prompt oxidizing of wraps. The cathodes with essential covering for welding steel with the yield strength of under 360 MPa, can be dried and put away at 2500C. This way dried cathodes before use can be cooled to a temperature of 150 to 2000C and put away in the stove for one-day use or hand dryers. Electrodes for high-alloyed steel ought to be dried at a temperature somewhere in the range of 200 and 2500C, for 3 hours. It is prescribed to warm and to cool electrodes, progressively. Wet terminals are effortlessly perceived by the sound from sway between them: dry cathodes give sharp and high strong, and wet ones produce profound sound. During welding with wet anodes, little blasts and snap sounds can be heard, and

dissipation of dampness can be seen from the surface.
Drying terminals of rutile type, without even a trace of different means, should be possible not long prior to welding by remembering cathodes for a short electric circuit.
Covered terminals will past during a period, which can be seen by little white gems on the wraps. This is the consequence of synthetic response of the covering fixings. These anodes should not be utilized. At last, be mindful so as to utilize just the terminals without mechanical harm or greasy (lubed) coverings.

2.3.3 Performance of the compound

When expected to completely perform weld joint entrance, and access is conceivable just on one side, frequently utilized is a cushion (washer) that fills in as the reason for the primary layer of weld metal (roots section), or forestalls spillage of the metal shower.
There are four fundamental kinds of washers:
(1) Underlay level washer strip

(2) Copper washer
(3) Non-metallic cushion (washer)
(4) Underlay (backing) weld.

Underlay flat washer strip

The level strip is a metal strip put beneath the notch, Fig. 44. The main weld associates the two plates of the base metal, and furthermore the level washer strip, which
may stay in the wake of welding if it's all the same to you, or be taken out by machining.

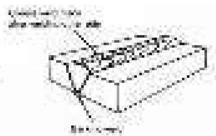



Figure 44. Washer strip Figure 45. Backing weld

Underlay washer strip ought to be made of the material that is metallurgically viable with an essential and extra material. In some cases it is feasible to utilize other helpful components as the washer strip liner, Fig. 44 (B). Regardless, the washer strip should be good to go, as far as its functioning surface condition, and as far as its math, so that there will be no issues sort of porosity and considerations or metal shower leakage.

Copper washer

The primary justification behind the use of copper as a material for the cushion is its enormous hotness conductivity, subsequently keeping the metal shower from softening the washer (cushion). It ought to be considered to have adequate thickness of copper washers. On account of sequential creation, water cooling ought to be accommodated copper washers to forestall neighborhood dissolving of the copper which might influence the last sythesis of the metal weld. The copper cushion can be formed to get the ideal shape of the root or stiffening.

Non-metallic pad

For non-metallic washer, we utilize granular material that produces slag or clay material.

Backing weld (Weld-pad)

The support weld root can likewise fill in as a cushion. Fig. 45.

Starting tiles

In some welding cases, it is essential, in any case, the alleged beginning plates, Fig. 46. This keeps away from any mistakes normal for the start of the work
(eg. Framing the electrical bend), and frequently a similar method is utilized in finishing the interaction, ie. on the finish of the plates that are welded.

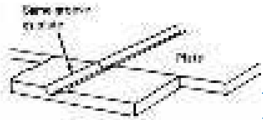


Figure 46. Beginning plate (tile)

2.3.4 Electric power types and sources, devices and equipment for MMA process

Device for MMA comprises of the power source, supply and return links, cathodes holder, the ground terminal, and the frill incorporate defensive dress, welders veil, and his hand devices. For MMA strategy, the two sorts of flows, single direction direct current (DC) and rotating current (AC) are utilized, and the choice relies essentially upon the kind of the cathode covering and is commonly suggested by the producer of the anodes. While picking the kind of force, we should consider the following:

(1) The voltage drop. A more modest voltage drop is acquired by applying exchanging flow (AC), which makes it more suitable on account of welding at more prominent good ways from the wellspring of electricity. (2) Small amperage. For more modest distance across anodes, or when utilizing more modest amperage, direct flow (DC) gives a more steady arc. (3) Establishing welding electric curve. Generally speaking, it is more straightforward with DC, especially with a more modest cathode diameter. (4) The curve length. Welding with the more limited circular segment is more straightforward by DC. This is significant, besides with iron powder cathodes coating.
(5) Arc twisting. It very well may be a critical issue with DC.
(6) The place of welding. For the constrained position, DC is a superior arrangement, since it can utilize less amperage.

(7) The thickness of the base material.
Welding of slight sheet metal can be an issue with AC because of diminished solidness of the curve while utilizing power of lesser strength.
Regardless of the sort of power, we utilize a source with steeply declining static trademark, since it gives a little change in the force of power at the unintentional difference in the bend length, that are unavoidable for manual welding.

On Fig. 47 is told the best way to change the current (Ir1 and Ir2) and voltage (UR1 and UR2) with expanding curve length (l1 to l2). As found in Fig. 47, the voltage change is huge, while an electric flow strength (amperage) is little. Since the difference in the voltage doesn’t essentially influence other welding boundaries, steeply declining trademark is getting sufficient nature of the welding, on the grounds that the cycle boundaries that are generally reliant upon the strength of the current are kept up with in the tight limits.

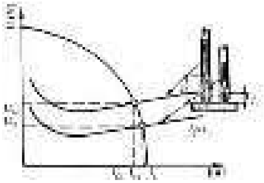


Figure 47. Changing the working point at steeply declining static characteristic

Circuit standing by voltage, U0, is voltage with a power source on, yet without electric curve. Sitting circuit voltage is decreased by setting up the bend, contingent upon the circular segment length and sort of terminals, and it becomes curve voltage. Normal benefits of sitting voltage load are 50-100 V, and the circular segment voltage 17-40 V. The higher OCV (open circuit voltage) gives simpler making of circular segment, however it is more hazardous for welders. Some power sources can change the voltage of sitting, however not all. In choosing the power source we should consider the following:

1. The kind of electric power
2. Required measure of current
3. Sources intermittency

Choosing the sort of force relies essentially upon the sort of terminal and the sort of welded joints. For AC (exchanging current) we use transformers, while the DC utilizes rectifiers (with the transformer) or converters (motor generator). Assuming you really want to have the two kinds of flows accessible, than single-stage transformer-rectifier or generator-rectifier are utilized, and as of late increasingly more frequently inverters are utilized due to low weight.

Electrode holder on one side is a conduit that gives the progression of the electric flow from the source to the terminal, and on the opposite side, it is a cover, which guarantees safe activity of the welder as it isolates (segregate) his hand from electric power. The jaws of the holder, which are in direct contact with the terminal, should be in great condition and ought not make more noteworthy protection from the electric flow stream, to keep away from overheat. Welding links associate the power source with the workpiece and with the cathode. Conductive piece of the link is curved copper or aluminum wire, which is isolated from the covers with the defensive protecting layer. Welding links are delivered in various sizes, which links are utilized relies upon the necessary strength of the flow and obligation pattern of the welding.

Protective attire and veil for welders, just as other defensive measures, are fundamental in all electric bend welding processes, particularly in MMA system. Risks by bend welding are an electric shock, too solid light, dirtied air and sprinkling of slag and metal. To forestall electric shock, the gadget should be guaranteed with severe intermittent control of defensive protection and establishing. Defensive attire is produced using a unique working garments, covers, gloves, shin and upper arm, and the main job has a defensive veil, without which the circular segment ought not be taken a gander at. On the covers, there are various opacities of glass, and the level of a mistiness is communicated by numbers (up to 14). In the accompanying text there is an outline of the fundamental protecting glasses for welding by MMA terminals of various thickness:

The electrodes with diameters (and used Shading amperage)

- up to 4 mm (up to 200 A) 10
- 4 to 6 mm (up to 400A) 12
- more than 6 mm (over 400A) 14

Intermittency of source

The work of the power source is usually performed by periodical turning on and off for replacement of electrodes, inspection, and cleaning of welds, respite, and others. And it is characterized by the ratio of the duration of load (welding) and the duration of the working drive cycle. Under the duration of the drive cycle is meant the total time (duration of load and break, or idle time). The relationship between the load duration and the duration of the drive cycle is called duty cycle or Intermittency (i):

$$i = \frac{t_o}{t_o + t_{ph}} \times 100(\%) = \frac{t_o}{t_c} \times 100(\%)$$

Where:

I - Intermittency;
t0 - span of burden (welding);
tph– length of idling;
tc - length of the working cycle.
Thus, the power source is situated in the supposed discontinuous drive, ie on the other hand changing activity under load (welding) and respite (standing by). During load time (t0) power source can’t arrive at the greatest temperature, and it can’t be completely cooled during sitting (tph). Along

these lines, the power supplies don ’t need to be thermally dimensioned to the greatest worth, ie. for I = 100%, however to some minor worth, contingent upon the driving cycle, or utilization of the power source. The power source is dimensioned for discontinuous activity, and irregularity is controlled by guidelines. For the constant activity of transformer (robotized welding) discontinuity is 100%, and for the manual welding, it is 60%. Discontinuity of the power hotspot for support work is 35% and for the semi-mechanized welding 70% - 80%. For manual curve welding, term of the working cycle is dictated by the norm and it is 5 min. Assuming the source has an irregularity I = half, this implies that we can't trouble it to 1 hour of constant work during 2 hour time, yet it very well may be consistently stacked greatest 2.5 min (at most extreme current) and after stopping for a moment (inactive work) of 2.5 min, it can again work (weld) persistently 2.5 min and so on alternating. In the specialized aides of each power source are given data about discontinuity and the most extreme measure of current can be applied at that discontinuity. Welders ought to hold fast to the evaluated irregularity of the power sources on the grounds that the power supply is intended to it and each compelling of the source outside these limits of discontinuity drive, can prompt its destruction.

If you know the intermittency of the source (i) and maximum current (I_{max}) for that intermittency, then you can use the formula:

$$I_{tz} = I_{max} \times \sqrt{\frac{i}{100}} \text{ [A]}$$

to ascertain amperage of welding that the power source could give for all time (constantly). In the above formula:
Itz - strength of consistent welding current;
Imax - greatest amperage welding;

I - intermittency.
Eg., A source with the maximum welding current of 400 A and intermittency of 60% can permanently be burdened by the welding current strength:

$$I_{tz} = 400 \times \sqrt{\frac{60}{100}}\ [A] = 309,8 \cdot 310\ [A]$$

With a most extreme welding current force of 400A and irregularity of 60%, taking into account the normalized time drive cycle tc = 5 min, the power supply would work for:

to = 0.60 x 5 = 3 [min]
and afterward would need to make an interruption (standing by) of 2 minutes thus alternately.

2.3.5 Welding Technology

Welding innovation incorporates the readiness of the base material, the choice of anode, choice of boundaries and welding strategy. In the arrangement of the base material, the most significant are molding (planning) the notch, and now and then it is important to clean the encompassing region to the metal sparkle. When picking size and state of the furrow, other than the thickness of the base material, it ought to be considered the roots availability, anticipation of the weld drops appearance, misshapenings of the welded joint and as lower as conceivable utilization of extra material. The arrangement with the most reduced load of the crease is by the standard the arrangement with minimal twisting of the welded joint, as it presents at least hotness. Openness to the root and forestalling through-weld drops (stream) needs inverse measures: In the primary case, the distance at the root ought to be pretty much as extensive as could be expected, however in the second case as little as possible.

The edge crease (join) is appropriate just for sheets more slender than 2 mm and is ready by twisting and fixing the edges. “I” groove is reasonable for sheets with a thickness of 3 to 5 mm and is ready by level removing the edges. The“V” groove is reasonable for a sheet thickness of 3 to 20 mm and is ready by inclining edges, typically at a point of 60°. The separation from the root ought to be pretty much as extensive as conceivable to give admittance to the cathodes however is confined by the prerequisite for a base utilization of extra metal and the most un-conceivable distortion of the welded joint. For objects with bigger thickness is utilized“Y” furrow, or “V” groove with dulling at the root, accordingly decreasing the danger of through weld trickles. Then again, this type of the furrow expands the danger of slag considerations in the weld metal, so by the standard, the “Y” groove is performed reciprocally (on the two sides), in how the root is established, and afterward re-welded on the opposite side. Likewise, in instances of pieces with bigger thickness “X” groove is utilized, or two-sided “V” groove, subsequently diminishing deformity, specifically, calculated distortion, which typically happens in thicker and longer plates with “V” groove. Also, the space of “X” groove is basically more modest than for the relating “V” groove, so that gives huge reserve funds of extra metals. Essential suggestions for the decision of structure and aspects of notches are given in ISO 9692-1:

Diameter and covers sort of anodes are picked by the base material and the particular prerequisites for the specific issues of welding. The distance across of the terminal is normalized by the accompanying arrangement: 2; 2.5; 3.25; 4; 5; 6; 8 and 10 mm, and it is chosen by taking the greatest breadth permitted by the size of the furrow. On account of multi-pass welding, for the crease base of the weld, we use terminals of 2,5 ÷ 4 mm, and for filling the depression anodes of bigger breadth are utilized, contingent upon the thickness of the base material. Notwithstanding the essential suggestions for choosing the width of cathodes, the kind of force, position and welding succession ought to be additionally considered.

Welding position altogether influences the decision of anode (covering). The cathodes with a film (slim) - covering or medium thickness covering are primarily chosen for constrained welding positions. What’s more to forestall spillage of fluid weld metal we use rutile or cellulose covering. Essential rules in the decision of terminal coatings are the following:

- Carbon and low alloyed prepares: the strength of the weld metal ought to be equivalent to or more noteworthy than the strength of the base metal. On the off chance that you search especially great durability, utilize a fundamental coat, just as on account of bigger thickness and solidness of structures.
- The mix of carbon and low alloyed prepares: With butt joints, the cathode is picked by the steel of lesser strength, and with the corner joints to the steel of higher strength.
- High-alloyed prepares: weld metal ought to

have the strength essentially as the base metal.

- Non-ferrous metals and composites: the terminal is picked by the base material since there are the same anodes for one material.

In the determination of boundaries should remember principally the sort, extremity, amperage and voltage of force, length of the electric curve, slant point and course of development of the terminal and welding speed. Current sort is picked relying upon the anode covering. For acidic, rutile and oxide covers frequently can be utilized exchanging or direct current with direct (straight) extremity (negative shaft at the cathode) DCSP, while with the base covers, generally speaking, is utilized direct current with circuitous (switched) extremity (in addition to post at the terminal) DCRP. Reliance of weld crease shapes from current kind is displayed in Fig. 48, which shows that the welding entrance is the biggest for DCRP, and the least for the DCSP, the effect on the camber is turned around, and impact on the crease width impact is immaterial. Some unacceptable decision of the current sort and extremity prompts deformities like porosity, shaky circular segment and more prominent exploding and splashing of extra metal during welding.

DCRP AC DCSP Figure 48. Reliance of weld shape on the kind and extremity of current

Electric Current Power consumption significantly affects the shape and mechanical properties of the weld joint. With increasing strength of the current, the weld superelevation (cumber or overshoot) and the weld penetration will also increase, while the width of the seam is virtually unchanged, Fig. 49. Too big current power gives coarse grain structure of the weld metal and increases burning of alloying elements. Insufficient strength of the current will give shallow depth of a weld and a weak bond between seam and base metal. In either case, the occurrence of slag in hardened weld metal is very frequent, as a result of the melt turbulence and its withdrawal in depth with too strong currents, or bonding for groove sides at too low voltage. Therefore, the correct choice of electrical current has crucial importance for obtaining a quality weld joint. For welding in forced position, electric current strength is reduced by about 20%, while for highly productive electrodes, we use stronger currents.

 → **I**

Figure 49. Reliance of the weld shape from the electric current

By expanding the width of the terminal, we will build the hotness dispersal and lessens the flow thickness, which limits the crease and builds the weld infiltration, Fig. 50.

 → de

Figure 50. Reliance of the weld shape from the cathode diameter By speeding up we lessen the measure of disintegrated extra and base metal, which influences the elements of the crease with the goal that the crease width diminishes, the weld entrance increments to a

specific worth and afterward diminishes, and the superelevation diminishes right away, and later it develops, Fig. 51. Insufficient welding speed causes errors such as slug appending and slag incorporations, and too quick welding gives too enormous superelevation of the seam.

 → v

Figure 51. The impact of welding speed on the crease form

Arc voltage has little impact on the state of the crease, particularly assuming that we remember the little scope of changes at MMA methodology, 22-32 V. Expanding the curve voltage builds the crease width, and changes of the weld infiltration and stature contrasts are minor.

By expanding the length of the bend we will build the width of the crease, and lessen the weld entrance and superelevation, Fig. 52. The too short circular segment will“drench” in the dissolve, expanding the choppiness of fluid metal which“runs” to the unheated spaces of the section, which gives low quality joint with mistakes of the slag connecting and considerations. Then again, a too long bend is temperamental and dissipates the extra metal. It ought to be borne at the top of the priority list the impact of the (covering) of anodes to the curve length. For acidic and rutile (covering), prescribed circular segment length roughly equivalents to the width of the cathode, and for the base covering and for the terminals of non-ferrous metals suggested is the twice more limited bend length, chiefly for better assurance of the metal bath.

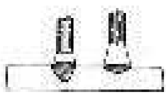


Figure 52. Reliance of weld shape from the circular segment length

The incline of the cathode in a plane opposite to the plane of the item to be welded influences principally the weld infiltration and less significantly the crease width and superelevation. The most extreme profundity is accomplished at the point of 90 °, or when the terminal is opposite to the outer layer of the welding, Fig. 53. The decision of cathode incline relies upon the base material, anode covering, welding position and kind of joint.

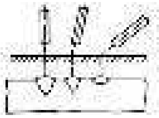
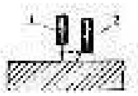


Figure 53. The impact of the terminal incline to the crease form

2.3.5.1 Welding technique

Establishing the arc, besides touching and moving away (Fig. 54a), is also possible by pulling the tip of the electrode, with the move to the necessary distance (Fig. 54b). The second way has an advantage, because the arc is established without damaging the electrode coating, and the arc length is regulated by the increase, and not by its reduction, which is far easier.


a)

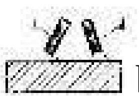
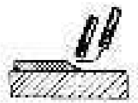

b)

Figure 54. Building up the curve: (a) the

approaching slip, moving close and away (b) pulling withdrawal

Ending the electric bend is best finished by pulling back the terminal (Fig. 55b) on the solidified slag and afterward moving it away. With the immediate raising of the terminal (Fig. 55a), a porosity blunder type can happen in the seam.

 a)

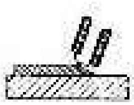
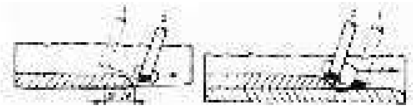
 b)

Figure 55. End the curve a) wrong; b) correctly

Particular consideration ought to be paid to proceeding with the intruded on weld stitch (crease), because of the pit which can happen throughout the break toward the finish of the weld. To try not to fill the cavity “on cool”, exceptional procedures are applied, contingent upon the kind of weld (root or filling), as displayed in two projections in

Fig. 56. In the primary case (roots weld - Fig. 56a), the circular segment is set up at 15 to 20 mm from the finish of the weld, on the generally executed weld root, whereupon bend goes to the root, to fill the furrow. In the subsequent case (weld fill - Fig. 56b), the arc is established at the bottom part (previous weld) or on the groove side, then returns back to the current weld and then it continues with further groove filling.



a) The underlying foundations of the weld
b) weld fill
Figure 56. Proceeding of the welding

Often when playing out the MMA welding system supposed swinging anodes is utilized, ie. filling its notch with anode cross over movement (and not just longitudinal), Fig. 57.

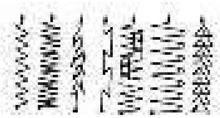


Figure 57. Essential methods of swinging the electrode

2.4 Gas metal arc welding (GMAW) MAG / MIG PROCESS - arc welding with soluble electrode wire in shielding gas

Arc welding with soluble electrode wire in a gas shield is the procedure of connecting metal by melting and solidification of the part of the base metal and filler metal (electrode wire) in which the protection of the molten

metal is performed by use of the inert and active gases or their mixtures. Curve welding with dissolvable anode wire in safeguarding gas is schematically displayed in Fig.
58. Contingent upon tHe sort of the safeguarding gas, metal circular segment welding with solvent anode is abbreviated set apart as MAG (Metal Active Gas) or MIG (Metal Inert Gas), wherein the MAG cycle utilizes CO2 as an insurance (carbon dioxide) or a combination of gases that goes about as a functioning gas, and in the MIG interaction Ar, He, (Argon, helium) or a combination of gases that goes about as a latent gas.

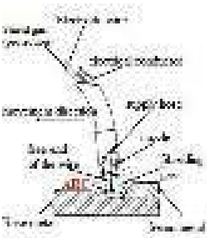


Figure 58. Curve welding with dissolvable anode wire in safeguarding gas

• The benefits of the strategy are:
- Universal application from the base material place of view,
- High speed of melting,

- High welding speed,
- Relatively straightforward welders preparing (for unalloyed and low alloyed steels),
- Simple hardware process,
- Applicable in constrained positions,
- Small venture costs (for the standard version).

• Disadvantages of the cycle are:
- The danger of mistakes in the start of welding,
- The danger of blunders in the lethargic welding, as a result of a fluid metal spilling before the electric arc,
- Relatively convoluted welders preparing (for instrument steel and non-ferrous metals),
- Difficulties in welding in the outdoors (flow).

Today around 60% of world utilization of filler material goes on the terminal wires for MIG-MAG. Fundamental applications are for metal industry, metal development, ships, pressure vessels, engine vehicles.

2.4.1 Transfer of additional materials

The principle methods of transmission of filler material are a stream (splash) transmission, hamper and globular exchange (move into enormous drops), Fig. 59. Notwithstanding them, lately, various better approaches to move extra material, has been grown, most quite drive, pivoting, STT (Surface Tension Transfer) transfer.

The stream (shower) move is feasible to accomplish with a current force more noteworthy than an edge esteem, fundamentally in the assurance of Ar (or He) since CO2 safeguarded filler material detonates (with Steel, it is required essentially 80% Ar combination and the unadulterated Ar for the ferrous materials). Shower move is appropriate for welding thicker plates since it utilizes high amperage.

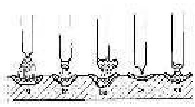


Figure 59. Ways of moving extra (filler)

material: a) shower move: the exchange in the stream; b) globular exchange: move of huge drops in a long
circular segment: b1 - the development of drops, b2-offbeat smothered drop; c) impede: c1-the arrangement of a drop, c2 - move of drops

Short circuit move is accomplished by utilizing the littlest current power and the littlest wire distance across. Along these lines, the welds are gotten with a little segment, and they can cool quickly, which is appropriate for joining meager sheet metal. What’s more, impede is reasonable for interfacing the bigger openings of the score, and for joints which need as little as conceivable twisting, in light of the fact that these bends bring a limited quantity of heat.

Transfer into enormous drops (globular exchange) is by all attributes between the past two. This exchange of filler material happens principally with the utilization of CO_2, and the amperage and voltage of the bend comprise “cross-area” in contrast with the past two methods of move. The nature of the joint is by and large substandard due to inadequate through welding.

The best effect on the exchange method of the filler material have the boundaries of the electric flow (type and power attributes of the source), the defensive gas, the sythesis of filler material and the free length of the anode wire. By expanding the force of the electric flow, the exchange of the filler material changes from short out to shower move, yet just with Ar as the safeguarding gas. It ought to be borne at the top of the priority list that the electric flow with a lot of force joined with expanded length of the free finish of the anode wire, can create pivot of liquid filler metal and its turning out of the metal shower Fig. 60, which restricts the decision of amperage.

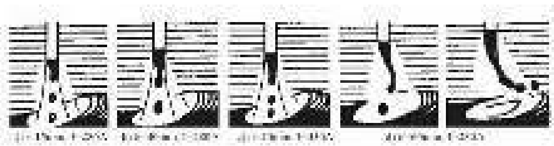


Figure 60. The impact of welding current (I) and the free length of the terminal wires (δ) on the

exchange mode

For the situation of Ar (Argon gas) insurance, the splash move might be accomplished by adequate amperage, which relies upon the distance across of the cathode wire. The impact of the electric flow power is comparable with other defensive gases however relies upon different factors moreover. Of the relative multitude of defensive gases just Ar, with adequate power, can ensure the splash move. Helium, albeit idle like Ar, when in doubt, gives the globular exchange, paying little heed to the sort and the force of the electric flow. Then again, He gives preferred weld infiltration over Ar, and the shower move can be accomplished by adding basically 20% of Ar, which likewise altogether diminishes the dangerousness of He and gives huge viable utilization of these combinations. Splash move at MAG system can be accomplished simply by backhanded extremity, which is oftentimes utilized (+ post on the wire) assuming that it meets another conditions (Eg. the expansion of sodium and cesium in the defensive layer covering of the anode wires). Clearly, dynamic gases, CO_2 and N_2 (nitrogen), similarly affect the transmission of the filler (extra) metals as He, alongside extra issues, particularly with direct extremity. With steel welding, latent gases display specific weaknesses when the exchange of extra metal is being referred to (winding down curve the hub, splashing of the filler metal), which can be diminished or disposed of by the option of O_2, or other dynamic gases, for instance CO_2, which decrease the surface pressure of the drops of extra metals. The beneficial outcomes of the expansion of O_2 and CO_2 even in tiny sums, are perceptible, yet by and by regularly a combination of 1-5% O_2 and up to 20% CO_2.

For the situation of a combination of Ar with over 25% of CO_2, the circumstance is unique. CO_2 separates on
≈3000 °C, its warm and electrical conductivity at that temperature is awesome. For directing power, just a little problem area on top of the wire is sufficient. The hotness is moved distinctly to that point at the highest

point of the wire. The free finish of the wire is considerably more warmed than remote pieces of the wire, so the exchange of extra metal is unpredictable, frequently shortcircuited, with a huge burst.

Notwithstanding these three methods of move of the extra metals, expanding application has drive move, which in the method for quality can arrive at TIG welding. The principle component of this method of move is the chance of managing the size of a weld drop (stroke or trickle) as indicated by the recurrence of dribbling. The circular segment is without short out and it is set up by motivation electric flow from helper sources. Beat recurrence, and consequently the quantity of drops in a timeframe might be changed. Experience has shown that the ideal recurrence of the beat compares to the recurrence of the city’s organization (of 50 or 60 Hz), and practically speaking are utilized in the recurrence range 20-120 Hz. The electric power source should give two degrees of flow power, the essential level, which ought to be sufficiently low to forestall

shower move and throbbing level Fig. 61, which is essentially over the level required for move. Subsequently, in one cycle, only one drop is
moved, but since it is feasible to set time span of cycles and the measure of current, it empowers acquiring the important nature of the association (joint). Utilizing the depicted rule in later occasions, a few adjusted variant of drive transmission have been created, specifically on account of utilizing inverter power source, which becomes predominant in the utilization of MAG/MIG process, since they give the best weld quality.

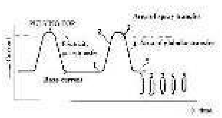


Figure 61. The quality of the beat move current

Application of the exchange strategies for the extra materials (sorts of arc).

• *Short bends - meager sheets, constrained positions, roots section with a little force of the current.*

Metal exchange through the metal circular segment – in a short out with few drops, Fig. 62. The recurrence of a short out 20 to 120 Hz.

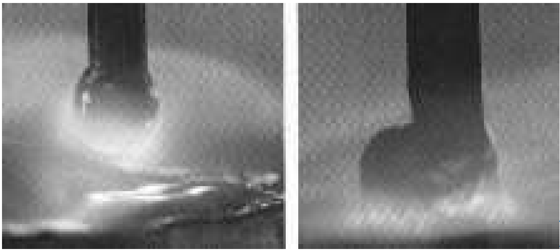


Figure 62.

• *Medium curve - for sheets of medium thickness - in blends dependent on Ar, the medium force of the electric flow*. Move into enormous drops, however with less scattering than in a long bend in CO2.

Recommendation: Avoid!
• *Long curve - for thick plates, high force of the electric flow, insurance in* CO2. Move into huge drops, with a burst.
Suggestion: Avoid!

• *Arc with splash move, Fig*. 63. - for thick plates, high current power, Ar or a blend based on Ar. Move into minuscule beads (shower), no short out, very little splash.

• *The pivoting circular segment Fig*. 64. – exceptionally thick pieces, extremely high current power, an extraordinary combination of Ar and He.

• *Pulse curve Fig*. 65. – General use, for any measure of current power, pieces dependent on Ar (not CO2). Metal exchange without shortcircuiting, controlled drop size and recurrence. A base conceivable bursting.

Figure 63. Splash transfer

Figure 64. Pivoting arc Figure 65. Beat arc

2.4.2 Shielding Gases

The most regularly safeguarding gases utilized are argon, helium, carbon dioxide, nitrogen, and hydrogen and oxygen (in little amounts) in the blends. The most usually utilized defensive gases, as indicated by EN 439, and their blends are displayed in Tab. 14, along with subtleties of their conduct, application, and properties. Effects of some protecting gases on innovation elements of the interaction are given in Tab. 15.

Table 14. Shielding gases and their mixtures - application and properties **Gas**
Symbol
Behavior
Application
Characteristic of the arc
Ar (99,998%) I1 inert

He (99,99%) I2 inert Ar+(25÷75%)He I3 inert
N_2 (99,9%) actively

Ar+(25÷30%)N2 inert Ar+2,5%CO2
M1-1
practically inert
Ar+(1÷3%)O2
M1-2
practically inert

Ar+(4÷8%)O2 M2-3 Oxidizing Ar+(1÷15%)H2

R2 Reducing CO_2 (99,9%) C Oxidizing Ar+ (26÷40%)CO_2 M3-1 Oxidizing Ar+6÷13%CO_2+3÷5%O_2 M3-2 Oxidizing CO_2+20%O_2 Oxidizing

all metals other than steel

Al, Mg, Cu
Al, Mg, Cu
Cu

Al, Mg, Cu

high-alloyed CrNi steels
high-alloyed CrNi steels
carbon and low alloy steels
high-alloyed, Ni steels
carbon and low alloy steels
carbon and low alloy steels
carbon and low alloy steels

carbon steels
greatest stability

increased thermal power
between I1 and I2 increased thermal power
increased thermal power

Spray transfer
Spray transfer
Spray transfer

big welding
penetration

possible splash (spatter)
possible splash (spatter)

little splash
possible splash (spatter)

TIME Gas: 26.5% He, 8% CO_2, 0.5% O_2, Ar is the residue

The utilization of dynamic gases requires extraordinary consideration as a result of oxidation. This peculiarity, which is generally normal for the traditional welding processes, is especially communicated when CO_2 is utilized as a defensive gas since then the accompanying synthetic response is played:

$$2CO_2 \quad 2CO + O_2$$

⇔ The course of this response relies chiefly upon the temperature so that at higher temperatures separation (deterioration of gas) is performed, and at lower temperatures affiliation (association of gases) is performed. Thusly, a structure of the gas blend relies upon the temperature Fig. 66, so that beneath 1600°C there is just CO_2 and with a temperature rising, the extent of CO and O_2

increments, so that at 3800°C there is just 7% CO_2, with 62% CO and 31% O_2. Subsequently, the oxidation is far the most articulated in the focal piece of the curve, where the temperature is most elevated, and it is the most un-articulated on the outer layer of the metal shower, where the temperature is a lot of lower. Hence the fundamental issue at MAG is to decrease oxidation of the extra metal drops, during their exchange through the arc.

Table 15. Shielding gases and their mixtures - technological characteristics

characteristic Ar/CO2

Welding
penetration Normal position forced position

Gun thermal overload

Oxidation speed Good, safer protection with an increase in % CO2

Ar/O2

Good, may become critical due to leakage in

front of metal baths with increased flow
Good, safe

Decreases with % increase in CO_2
Increases with higher % CO_2 High

High
(Especially at 8% O_2)
Low (due to good thermal
conductivity)

High
Porosity
Splash
Introduced heat

Mechanical and technological characteristics

Ability to fill the gap at the root

Decreases with higher%
CO_2

Grows with higher % CO_2

Increases with % CO_2, less cooling rate,

reduces the risk of cracks
Good, medium with CO_2>30%

Increases with decreasing % CO_2

High Low
Without bursting

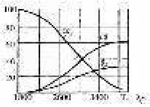
The highest, High speed of cooling, the risk of cracking
High, growing with increasing power of the arc

High, Small cooling speed,
Small risk of cracks

Good, medium with CO_2>12 Medium good
CO2
Lower than in the gas mixture

The transfer of material through arc
Short arc Medium arc The pulse (CO_2 <20%) The rotating arc
Short arc Medium arc The pulse arc The rotating arc

The composition of mixtures%



Short arc Long arc

Figure 66. Piece of gas combinations at MAG procedure

Argon is a dormant gas, a dreary, unscented and dull. Albeit not toxic, it ought to be noticed that Ar in a shut room can lessen the convergence of oxygen. Argon is a normalized for quality, use, testing strategies and conveyance technique. Argon relying upon the immaculateness is delivered in the four characteristics: of A (99.999% Ar), B (99.99% Ar), C (99.96% Ar) and D (85% Ar). Ar quality C is utilized for welding and in unique cases Ar Quality B can be utilized. Argon is provided in steel compartments set apart in yellow tone, 40 l volume and strain up to 200 bar, wherein the jug gets 6 Nm3, or 10 kg of argon. Bottle with Ar isn't discharged to the end in light of the fact that adequate overpressure should be left in it to forestall entrance of air into the bottle. Carbon dioxide gas is drab and unscented, with acrid flavor. At a focus up 2.5% CO_2 isn't hazardous for inward breath (for brief time frame), however in higher fixations or during extremely durable impact it very well may be hurtful. Carbon dioxide is a normalized, put away in steel holders, set apart in dim dark, a limit of 40 liters and a strain of 70-100 bar, so that in each jug fits 15 Nm^3 and 30 kg of CO_2. A standard characterizes three quality for CO_2: specialized, unadulterated and strong (dry ice). For the welding, unadulterated CO_2 is applied with least fixation 99.8%.

2.4.3 Welding Wire

Electrode wires are created in loops, with a mass worth of 1-100 kg, in a breadth series from 0.8 to 1.6 mm with steps of 0.4 mm, and particularly 2.4 and 3.2 mm, wherein the wires of more modest width (up to 1.2 mm) are regularly utilized for move in enormous drops, and bigger distance across wires (over

1.2 mm) for move in shower and drive transmission. In the auto business wires φ 0.9mm, are likewise used.

For the situation of welding steel, anode wire ought to have a higher substance of Si and Mn all together for deoxidation of weld metal crease and remuneration of consumed components in the base material. To forestall the event of porosity in the weld metal and case-solidifying, the carbon content is restricted to 0.12%. In the decision of filler material, we ought to think about the substance arrangement and mechanical properties of the base material, condition and tidiness of the base material, position of welding and kind of extra material exchange. Terminal wires for welding are normalized per EN 440.

2.4.4 Sources of electricity and devices for welding

Welding gadget comprises of next parts: The wellspring of electric flow, the contraption for conveyance (supply) of wires, electric links, and burner, control framework for safeguarding gases, cooling framework, the overall order framework, a jug of protecting gas

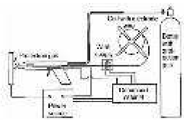


Figure 67. Plan of gadget for curve welding with dissolvable anode in safeguarding gas

The burner comprises of contact guide, spouts for defensive gas and components for fixing, Fig. 68. During activity, the temperature can arrive at 700°C (even at brief time frame welding), which prompts the slag adhering to the gas spout. To forestall this, particularly at higher amperage, water-cooled burners are utilized. During this we should consider the following:

• The gases that are rich with Ar, thermally more weight the burner contrasted with CO_2,

• The width of the contact guide should be greater by 0.2 mm (for steel), and by 0.5 mm (to Al) than the wire diameter.

• Contact guides ought to be of E-Cu, CuCr or CuCrZr. Supplanting the contact directs because of wear, when changing spools of wire (≈15 kg) is viewed as typical. The selection of materials for contact guides relies upon the application. E-Cu has the best electric conductivity, yet rapidly wears, while the circumstance is switched with the previously mentioned alloys.
• in the event that you really want to lessen the grinding between the contact guide and the wire to guarantee the smooth slide or the stock of the wire, the utilization of Teflon embed is recommended.
• A bundle of hoses length (links for power, gas and cooling water) ought to be pretty much as short as possible.

Figure 68. Burners for MIG/MAG procedure

In request to utilize the impact of circular segment length self-guideline, for bend

welding with dissolvable cathode wire in safeguarding gas, electric wellsprings of flows with a level or gently declining outer static trademark are utilized Fig. 69. Specifically, assuming the length of the bend increments with the goal that the curve attributes fluctuate from 1 to 3, Fig. 69, the force of the current altogether decreases, which in Fig. 69 is set apart with I1 to I3. Because of the abatement in amperage quickly liquefying pace of the cathode diminishes as well, and in this way the length of the curve. Then again, on the diminishes as well, and in this way the length of the curve. Then again, on the 1, Fig. 69), the current power increments from I3 to I1, and the length of the curve increments. In this way the length of the bend gets back to the underlying worth, which is
called self-guideline impact. Aside from the static qualities, power hotspots for MAG/MIG cycle ought to give better unique attributes comparable to wellsprings of power for the MMA strategy, particularly on account of short out move of filler material. Consequently, eg. to dial back the

progressions in the force of power later a short out, the acceptance loop is taken care of in the electrical circuit, which creates the outcome displayed in FIG. 70, which works on the nature of welded joints.

Figure 69. The impact of self-regulation
Figure 70. The electric ballast (suppressor) sway on electric flow power

For arc welding with soluble electrode in shielding gas as a rule is used direct current with indirect polarity (+ pole on the wire) because it provides a stable arc, steady transfer of additional materials (if necessary transfer in a spray, even when using active shielding gases), with small losses due to fragmentation and good characteristics of a joint in a wide range of amperage. Direct extremity is utilized on the off chance that it is important to get as less through welding (weld profundity) as could be expected, for instance with flimsy sheets, however its utilization is kept away from because of diminished circular segment strength. Exchanging current isn’t utilized due to essentially decreased the security of the arc.

Supply of wire is given by an extraordinary gadget, Fig. 71. There are various frameworks for bringing wires, Fig. 72. Lodge framework is applied to a fixed work environment, on the grounds that the loop wire and the drive system are situated in the lodging of the power source, Fig. 72a. In the widespread framework, the entire gadget for wire feed is situated out of the case, which permits it to work in different working environments and on the huge workpieces, Fig. 72b. Pair gadget has two drive system, one in the power source packaging, straightforwardly to the loop of wire, and the other close to working environment Fig. 72c, which additionally permits you to work on different work areas and on the enormous and out of reach workpieces.

The gadget type“push-pull” likewise has two drive components, in one the packaging as in the pair gadgets, while the subsequent drive is in the burner, so it pulls (“pull”) wire as opposed to pushing it (“push”), Fig. 72d. This gadget is appropriate for welding in blocked off places, where the loop wire can make the cycle superfluously troublesome and where the solid directing of the wire at more prominent distances is required. Standard working distances of certain frameworks are demonstrated in Fig. 72 a-d.

Figure 71. Plan of bringing wire: 1 - Pulley with wire, 2 - Guiding result, 3 - Rollers to direct wire, 4 - Drive rollers, 5 - Push roller, 6 - Front gulf guiding

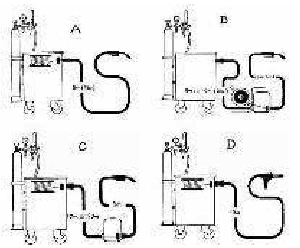


Figure 72. Frameworks for bringing wire: A) Cabin, B) Universal, C) Tandem, D) “push-pull”

Of specific significance on account of cored wire and other “milder” wire (nonferrous metals), is the utilization of the drive

component with four wheels, rather than two, since it guarantees the stockpile of wire with less strain, equally circulated on the two sets of rollers. The surface type of the wheel on which the wire lies is additionally significant - While the “hard” wires
common profile is looking like“V”, the “delicate” wire’s surface ought to be profiled, for instance as“ “.
It ought to be borne as a primary concern that the right decision of contact

∪ rails (guides) and the component for conveyance of wire, is urgent to the nature of MIG/MAG welding, particularly when it is utilized with stuffed wire or strong wire from non-ferrous metals and aluminum alloys.

2.4.5 Welding Technology

The fundamental boundaries of bend welding with dissolvable cathode wire in insurance gas are the sort and force of the momentum, curve voltage, the speed of wires feed, wire width, wire free part length, wire slant (point), welding position, type and stream of the protecting gas.

Electric flow type and amperage altogether affect the elements of the crease, as clarified at MMA methodology. With different boundaries at the steady worth, the reliance of the cathode wire softening pace and current power is straight for lesser amperage esteems, and at higher current power esteems, particularly with more modest breadth wire, reliance becomes nonlinear (Fig. 73). The reason for this is the warming of the wire free end by the electrical obstruction. Likewise with MMA strategy, for the consistent wire conveyance rate, bigger measurement wires require higher current, yet with MAG/MIG process the non-linearity of this reliance is more articulated. For instance for the wire supply speed of 5m/min required ebb and flow power is 85A for the wire measurement of 0.8 mm, or 325A for the wire width of 1.6 mm.

The free finish of the wire should be inside sure cutoff points since its exorbitant length causes overabundance filler material and a lacking measure of hotness for its refining, which gives shallow welds and negative crease shape. Then again, decreasing the length of the wire free end makes the circular segment temperamental. It ought to be noticed that by the expansion of the wire free end length its electrical obstruction and the level of warming are additionally expanded, and the lower flow power is required for wires liquefying. Experience shows that the short out move requires the wire free end length of 6 to 12.5 mm, and for alternate methods of move from 12.5 to 25 mm. Notwithstanding the wire free end length, the distance between the gas spout and the base material fundamentally influences the welding. On one hand, spout distance ought to be pretty much as short as conceivable all together the assurance by the gas to be more proficient, and then again, too little distance opens spout to the unnecessary hotness and diminishes welder capacity for visual control of welding zone. The free finish of the wire, just as the distance between the aides and spouts from the base material, are displayed in Fig. 74. Depending

on the current power there are three related places of the wire free end and spouts for gas:
- The free finish of the wire is more limited than the spouts distance, for current power 50-150A, Fig. 75a
- The free finish of the wire is equivalent to the spouts distance, for the amperage 150-350 A, Fig. 75b
- The free finish of the wire is longer than the spouts distance, for the current control north of 350 A, Fig. 75c.

As a general rule, the increment in the current power essentially builds the wire free end length, and less significantly expands spout distance too.

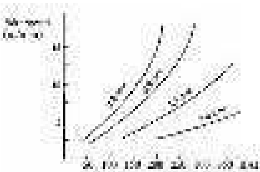
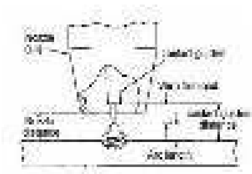
 

Figure 73. Reliance of the speed of bringing anode wires and the electric flow power I

Figure 74. Ordinary places of the wire free end and the spouts for gas

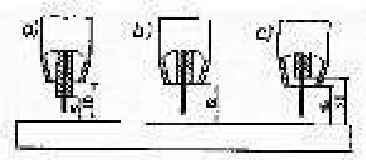


Figure 75. Ordinary places of the wire free end and the spouts for gas Arc voltage altogether influences the nature of the weld joint, on the grounds that an adjustment of its qualities can influence the method of the extra materials move and less significantly the components of the crease (similarly as in MMA technique). The impact of the voltage on the exchange of extra metal is displayed in Table 16, where are given the common the voltage esteems utilized for the welding of various metals in relationship to the sort of protecting gas. The impact of welding speed is as old as the MMA technique. Welding speed is picked relying basically upon the electric ebb and flow power, with respect to its worth, to keep up with the drive power setpoint and welding position (lower welding speed for constrained positions, given that the momentum power is lower).

The place of the burner impacts the state of the crease. Consequently, eg. slant of the terminal wire to the upward pivot basically changes the state of the weld crease from wide and shallow (slant toward welding, ie. welding forward method) to thin and profound (incline inverse to the course of welding, ie. welding in reverse method), Fig. 76.

Table 16. Typical arc voltage values for welding with shielding gas Voltage (V) Transfer in large drops Short circuit transfer

electrode diameter 1.6 mm electrode diameter 0.8m

Ar He 25%Ar-O2 CO2 Ar Ar-O2 75% ArThe most extreme weld infiltration is accomplished by the method of welding in reverse. Other than this, welding method in reverse gives a more steady curve, less crease porosity and less sprinkle of extra (filler) material.

He

On the other hand, taking care of burner and controlling metal showers are
Aluminum 25 30 29 -more straightforward with forward welding, which hence enjoys the benefit- 19 - -in welding meager sheets and root welds.
Carbon - - - 28 30 17 18 19
steelThe current power is chosen by the breadth of the cathode wire, on the Low alloy - - -28 30 17 18 19grounds that on account of deficient current power or curiously large width of
steelthe terminal wire, wire softening is lacking, and in the contrary case the

Stainless 24 - - 26 - 18 19 21 steel
presence of the sprinkle, porosity and sporadic math of the weld are run of the mill. As indicated by this, flow thickness (characterized as the proportion of the momentum power and cathode distance across), decides the crease aspects as follows: more noteworthy weld entrance and lower crease width are gotten by higher current thickness (or higher amperage for a similar measurement or more modest breadth for a similar current power).

Transfer of the extra material in shower and huge beads are commonly gone after welding in an even job, while the short out and throbbing exchange are utilized for all positions. For the welding in the vertical and overhead position, wires with a more modest distance across are utilized, and the short out or throbbing exchange of extra material, as this increment the impact of electrodynamic powers and surface strain, which permits conquering the impacts of gravity.

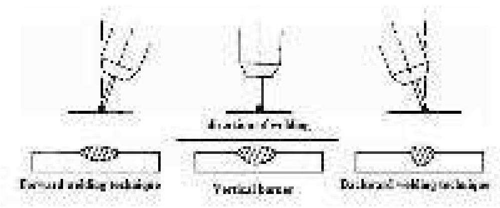


Figure 76. The impact of the incline of the burner to a crease form

The impact of the defensive gas type on the crease structure is given in Fig. 77. Notwithstanding the sort of defensive gases, a significant impact has their stream which relies upon the kind of weld joint, position and welding speed, size and state of the depression, electric flow power, circular segment voltage and wire width. When deciding safeguarding gas utilization, it ought to be noticed that on account of its lacking sum, encompassing gases can infiltrate into the metal shower, and the on account of security gas flood and high stream speed, choppiness with similar results occurs.

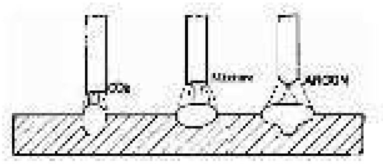


Figure 77. The impact of the defensive gas type to the crease form

When welding with shielding gas, you should bear in mind the flow of the surrounding air, which must not be such as to interfere with the effects of shielding gas. Particularly when working outside, you want to foresee a sufficient asylum from the breeze and constrained airflow.

2.4.6 Welding technique

The development of the wire top in multi-pass welding in a level position is displayed in Fig. 78, (the roots pass displayed in Fig. 78a, filling pass in Fig. 78b and covering pass in Fig. 78c). The burner is ordinarily moved with in reverse strategy, shifted at 25° to the vertical, besides with flimsy sheets, where forward welding method is used.

When welding is complete and power is turned off, the burner is kept above the metal bath another 5-10s, in order to ensure the protection of the weld metal seam. With the high safety importance structures, the electric arc should be terminated at the auxiliary output plate, and not on the weld metal seam. Errors in the MIG / MAG welding are given in Table 17 and shown in Fig. 79.

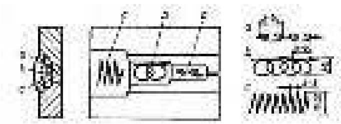


Figure 78 Movement of the wire top in the flat welding - butt joint

Error
insufficient binding

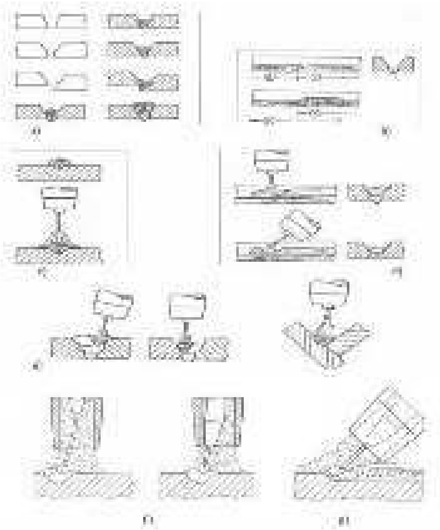


Figure 79. Mistakes in MIG/MAG welding

Table 17. Errors in MIG / MAG welding

a. preparation of the groove

Cause
Incorrect
b. Difficult arc establishing
c. Small power of the arc

Technological error Figure small angle of the 79a openings
a small opening hole or a
large opening height

big abbreviation of edges
technological probes not 79b used
sides poor preparation
insufficient overlap of the
welds
low voltage or low 79c electric current power
high-speed welding
d. The metal bath leakage in front of the arc

e. Wrong position of the electrode
porosity a. The burner is defective

b. Wrong position of the gun
the large free length of the wire
Higher power of the arc 79d and volume of the bath
Small welding speed
Big tilt angle of the wire
large free length 79e large contact nozzle
wrong order of weld depositing
large free length 79f contact nozzle deformed
a leak in the cooling hose a contact nozzle dirty
large angle 79g the great distance between nozzleworkpiece

c. Fast airflow
d. The magnetic deflection of the arc e. The wrong combination of gaswire
The high content of C, low content of Si and Mn (Wire)
The high content of O2 (gas) or humidity

f. Soiled (dirty) surfaces of the sides
undercuts

The high power of the arc high welding speed the insufficient swinging of the wire incorrect position of the gun

2.4.7 Setting the MIG / MAG welding device

Modern gear for MIG/MAG welding process has a control board with the likelihood to change all compelling working mode boundaries. Synergistic gadgets have the choice of putting away (recording) programs that contain boundaries for explicit welding strategies. For a decent weld, the ideal selection of boundaries is fundamental. Figure 80 gives an outline of one of the advanced welding apparatuses controls board, with clarifications of the singular keys capacities. Each producer of welding gadgets has an extraordinary control board and before use, make certain to peruse and conform to the first client guidelines for your welding apparatus.

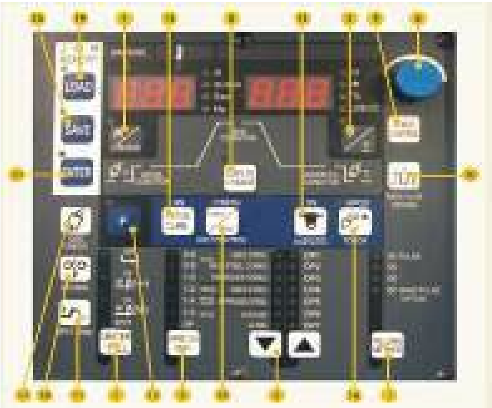


Figure 80. The control board of the welding gadget for MIG/MAG process, VPS 4000 digit.

1. Selection of welding process (DC beat, DC standard, MMA procedure).
2. The key for the decision of material and protecting gas.
3. Button for choosing the welding wire diameter.

4. The determination of momentum power, wire speed, beat term, and heartbeat rate.
5. The choice of voltage, voltage revision, the adjustment in %, choice of put away programs.
6. A guideline encoder for chose parameter.
7. Selection modes (ceaseless, spot, pulse).
8. Button for choosing capacities on the display.
9. Setting the curve characteristics.
10. The joining of WAVE PLUS choices (beat shape).
11. Key for guideline of time for spot welding.
12. Function key (select function).
13. Display the beginning current.
14. Selection key for synergistic or set free operation.
15. Turning on the steady profundity of weld penetration. 16. Election of a water-cooled torch.
17. Control gas flow.
18. Key for wires presentation in guides and burner.
19. Calling put away (recorded) program.
20. Storage (recording) of the program with

the chose parameters. 21. Confirmation of the boundary settings.

2.5 TIG welding procedure - arc welding with insoluble electrode in inert gas

Arc welding with non-consumable electrode in gas shield is the process of joining metal by melting and solidification the part of the base metal and filler metal (welding wire - if used), whereby inert gas is used as protection (active gases are not used, because they would cause the oxidation of the electrode top), Fig. 81.

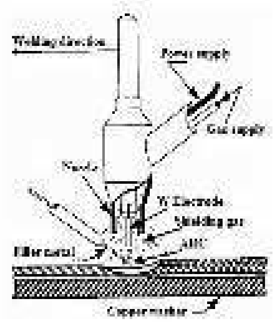


Figure 81. Schematic portrayal of insoluble anode circular segment welding

This strategy is truncated as TIG (Tungsten (otherwise called wolfram W) material terminals, IG - latent gas) or GTAW (Gas tungsten bend welding) and was initially presented as a technique for welding Aluminum and its compounds because of the impact of cathode cleaning. This impact comprises in breaking and eliminating the stubborn oxide Al2O3 filth from the metal shower or from its surface, by the impact of the electrons moving from the base metal to the terminal, subsequently forestalls metal statement in the lower part of the weld metal crease and empowers welding of Al. Right now, the utilization of TIG process is a lot higher, mostly because of a prevalent nature of the association, which is refined, in addition to other things, by better control of hotness input and extra metal by isolating the jobs of extra metal and the cathode. TIG welding is conceivable even without extra metal, which is particularly significant for flimsy metal sheets. Although it is essentially a manual (hand) technique, TIG can be mechanized, both as far as bringing the wire, just as in the feeling of directing the terminal. In regard to the MMA technique, principle benefits of the TIG are better insurance of the metal shower, the shortfall of slag (not time lost on substitution of the anodes and eliminating the slag in multi-pass welding), the chance of utilizing more modest wire width, or bigger current densities. Benefits of TIG process are especially apparent in the slight sheet metals, materials like non-ferrous metals and treated steels, just as weld root passes of capable joints. Then again, TIG technique isn't cutthroat with other curve strategies with regards to conservative welding of thick as well as long sheets of common underlying steel. The usefulness of TIG interaction can be expanded by use of the variation with a warmed wire.

Advantages of TIG process are:
- Top quality weld joint, mistake free,

- No burst - extra metal is dissolved in a metal shower, without communicating through the arch,

- Can be utilized without extra material,
- Excellent control of roots (form),
- Precise control of welding parameters,
- Applicable to an enormous number of base metals,
- Good control of the hotness source and methods of presenting extra materials,
- No slag,
- Any welding position feasible.

Disadvantages of TIG process are:
- Relatively little nuclear energy and productivity,
- Requires uncommon preparing for welders,
- Difficulties in ensuring the weld for outside welding.

2.5.1 Types of electric power sources

- Direct flow (DC) as well as exchanging flow (AC)
- DC is utilized for all base metals, aside from Al, Mg and different metals with hard oxides for which AC is used,
- Steeply plunging static characteristics,
- Newer power sources: semiconductor or thyristor, permit welding in cycles (Start, beating flow power and stop the arc)

- DC sources are normally with three-stage power - uniform burden on the power grid,

- AC source typically has a DC too,
- Older AC sources with single-stage flow - unequal heap of the power grid,
- Newer AC sources have less weight (more modest transformer) - with semiconductors (inverters).

In the TIG cycle, most generally utilized is substituting current (AC) and direct current with direct extremity (DCDP) (negative shaft at the anode). The impact of the current sort,

on the weld performed by TIG welding, is displayed in Fig. 82. Single direction direct flow with direct extremity gives the tightest and most unimaginable crease, Fig.82a. Welding heat is designated around 1/3 for every anode, and 2/3 on the base material. Ionized particles are guided from the material to an anode, and electrons from the terminal to the base material, so it doesn’t give the impact of surface cleaning of the hard-headed oxide, considering present realities for the situation with direct current with roundabout extremity (DCIP), Fig. 83a. Thusly, a single direction direct flow with an immediate extremity is utilized for welding metals for which the cleaning impact isn’t needed (steel, nickel, copper and their alloys).
Indirect extremity gives the most extensive and shallowest crease, Fig. 82b. Welding heat is assigned, in opposition to the past case that is 2/3 on the terminal, and 1/3 on the base material, which is nonsensical, gives unsteady bend and overheats the anode and burner. Although

direct current with backhanded extremity, because of the development of electrons from fundamental material to an anode, creates the outcome of surface cleaning of hard-headed oxides, with its given inadequacies its commonsense use is irrelevant, and rotating current is utilized for the welding of aluminum and its alloys.

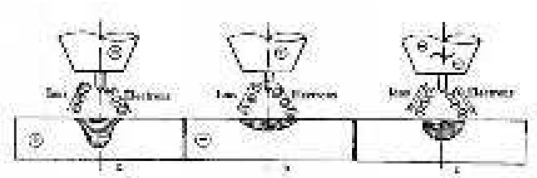
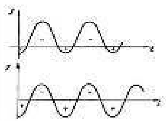


Figure 82. The state of the crease contingent upon the kind of power: a) DCDP; b) DCIP; c) AC

Alternating current provides a seam width and depth between the two polarities of direct current, Fig. 82c. Given the nature of alternating current (change of polarity 50 or 60 times per second), the electric arc is unstable. For this flaw of alternating current to be reduced to a minimum, the so-called high-frequency HF generator is used. The disadvantage is also the so-called unbalanced (asymmetry) current. It is about aluminum and tungsten different abilities to emit electrons, due to which the negative half period is increased at the expense of positive, because more electrons are emitted from tungsten electrode when it is on the (-) pole, Fig. 83b. The first consequence of this asymmetry is an almost one-way effect of the arc, which causes overheating of the welding transformer, and the second is the result of a significant reduction of cathode cleaning. To prevent this, a condenser battery (capacitor) is introduced in the circuit, connected in a series with the arc. And this capacitor has the task of increasing the positive half-periods, ie. to establish the symmetry of wave power, etc.. 81b. This also increases the cleaning effect, allowing the application of alternating current for welding of aluminum and its alloys. Therefore, newer transformers for TIG process are supplied with HF generator and capacitor battery.

a)



b)

Figure 83. a) The impact of cathode cleaning; b) The awry and symmetric types of AC periods

2.5.2 Insoluble (non-consumable) electrodes

Insoluble anodes are made of tungsten or tungsten and thorium compounds, zirconium or lanthanum oxide. For manual TIG process, there are four sorts of electrodes:

a) The anodes of unadulterated tungsten (known as W - wolfram) - Melting temperature 3410°C, delivered by sintering tungsten powder, virtue min. 99.5%, on the grounds that a higher extent of pollutants causes quick wear of electrodes.

b) Electrodes of tungsten, with the expansion of 0.9 to 4.2% thorium oxide (T-Th), which permits simpler outflow of electrons, which gives more straightforward foundation and support of the electric bend and further develops resistance to electric flow load. In addition, these terminals have expanded circular segment security at temperatures lower than 1000°C comparable to the cathodes made of unadulterated tungsten, in this way staying away from the fractional softening of the anode and giving a fundamentally longer assistance life. Fig. 84 shows the electric flow thickness reliance on the temperature for the T and T-Th electrodes.

Figure 84. Reliance of current thickness from the temperature for the T and T-Th electrodes

c) Tungsten anodes with zirconium oxide from 0.3 to 0.9%. These anodes by their properties and the cost are between the two above gatherings of terminals. They are applied distinctly with rotating current, and for welding aluminum and light alloys.

d) Tungsten terminals with lanthanum oxide from 0.9 to 1.2%. They are utilized for plasma welding, since they have a more drawn out life than other terminal variants.

In Tab. 18 are shown the sorts of insoluble cathodes, along with a process for naming as per EN 26848 and fundamental characteristics.

- Codification as per the synthetic sythesis: The
primary letter = the image of principle component
The subsequent letter = first letter of oxide + number (oxide content x 10)
- Terms of delivery:
- Diameters: 0.5; 1.0; 1.6; 2; 2.5; 3.2; 4; 5; 6; 8; 10 (mm)
- Length: 50; 75; 100, 175 (mm)
- Straight (strictly)
- Quality (without breaks, pores, inclusions).

Table 18. Insoluble (non-consumable) electrodes Material

tungsten (Additives Symbol Color %)
<0.2 WP green Remarks

Good stability in AC.
Problems when starting with DC. tungsten with 0.3-0.5 thorium ThO_2 oxide 0.8-1.2

ThO_2
1.7-2.2 ThO_2
2.8-3.2 ThO_2
3.8-4.2 ThO_2 tungsten with 0.15-0.5
zirconium ZrO_2 oxide 0.7-0.9 ZrO_2

tungsten with 0.9-1.2 lanthanum LaO_2 oxide
WT 4 blue Increasing the WT 10 yellow
content of ThO_2, WT 20 red increases life,
WT 30 violet allowed amperage WT 40
orange and improves start.

Th is radioactive!

WZ 4 brown The reduced WZ 8 white
tungsten inclusions in
weld metal seam (used for nuclear vessels).
WL 10 black Longer life of WT electrodes
(Plasma welding)

In inactive gas protected curve welding and in plasma cutting and welding, it is fundamental that the terminal is painstakingly chosen. Its inclination, breadth, surface condition and the kind of current utilized incredibly impact work quality and bend soundness. Inferable from the improvement of bend temperatures in the request for 4 000 °C, it is important to utilize a metal with an incredibly high softening point for the production of an anode which is non-consumable by definition. Tungsten meets this prerequisite and, furthermore, gives the upside of a high thermionic discharge; it is, subsequently, a superb material for making such cathodes. Certain substances, added during assembling of the cathodes, advance the electron outflow. The most widely recognized substances are thorium oxide (ThO_2), zirconia oxide (ZrO_2), lanthanum oxide (LaO_2) and cerium oxide (CeO_2), the measures of which range from 0,3 to 4 % relying upon the component. These imbeciles are liable for expanding the usable existence of the cathodes on account of their higher electron discharge, better circular segment beginning and bend strength. Adding these oxides diminishes the danger of tungsten debasing the welds. Given comparative breadths, terminals containing oxides can take a higher current than unadulterated tungsten ones; lower distance across anodes, therefore, might be utilized. The impact of oxide augmentations is additionally more observable with enormous measurement terminals in light of the more noteworthy size of the tip covered with a layer of emissive substance. 1. Scope and field of use This International Standard sets down necessities for tungsten terminals for dormant gas protected circular segment welding, and for plasma cutting and welding.

2. Definition tungsten cathode flow conveying exposed tungsten bar, with or without oxide added substance, filling in as anode or cathode for the age of an electric arc

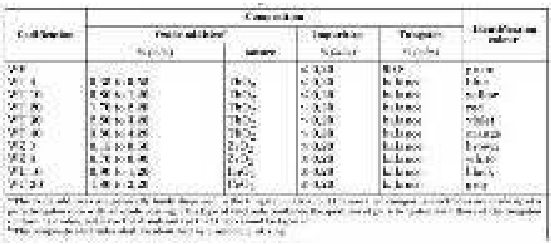
3. Composition Tungsten anodes might contain oxide added substances to further develop the outflow qualities. The synthetic organization of these anodes will be as per the necessities given in Table 18b.

4. Designation The codification of tungsten terminals depends on their substance sythesis as per Table 18b:

a) The main letter shows the essential element;

b) The subsequent letter demonstrates the oxide added substance (the letter chose is the underlying of the component name); the accompanying number is the mean oxide content increased by 10.

Table 18b— Codification, composition and identification color



[illegible]	Composition				Identification colour
	[illegible]		[illegible]	[illegible]	
	[illegible]	[illegible]	[illegible]	[illegible]	
[illegible]		[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	balance	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	balance	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	balance	red
[illegible]	[illegible]	[illegible]	[illegible]	balance	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	balance	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	balance	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	balance	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	balance	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	balance	[illegible]

[illegible]

5. Marking In understanding with Table 18b, tungsten terminals will be set apart based on their compound sythesis, with one (or potentially, as on account of composite cathodes, two) shading ring(s) toward one side of the anode. The width of each ring will be 3 mm or more.

6. Technical conveyance conditions

6.1 Diameter The breadth, communicated in millimeters, will be chosen from the accompanying reach: 0,5– 1,0– 1,6 – 2 – 2,5 – 3, 2– 4 – 5 –

6,3 – 8
– 10 The resistances on the standard sizes are as per the following: a) for diameters
< 2,5 mm: ± 0,05 mm b) for distances across
$ 2,5 mm: ± 0,1 mm

6.2 Length The length, communicated in millimeters, will be chosen from the accompanying reach: 50– 75 – 150– 175 with a resilience of ±
1 mm.

6.3 Straightness assumes a significant part in plasma cutting. To this end the anodes utilized for this reason will not go amiss from the straight by more than ± 0,5 mm over their length. They will be estimated along a generatrix.

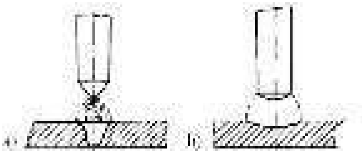
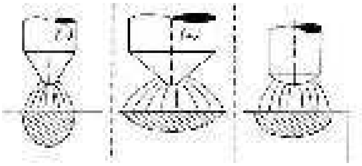
6.4 Electrode quality. The electrode shall show neither surface defects (micro-fissures, cracks, scale, etc.) nor internal defects (porosity, inclusions, etc.). The electrode surface shall be free of oil, grease or other impurities. The smooth and clean surface condition required may be achieved by dressing. The electrode tips, in particular, shall be perfectly dressed and free of burrs.

6.5 Marking of boxes or unit bundles The

accompanying data will either be printed straightforwardly on each case or unit bundle or show up on a stuck on name: a) name of producer or provider; b) breadth of the cathodes; c) length of the terminals; d) images for the substance sythesis as per Table 18; e) shading ID as per Table 18b.
6.6 Packing Tungsten terminals will be pressed with the goal that their surfaces are shielded from all harm or stain when they are appropriately moved and stored.

Not just material yet in addition the type of the terminal top essentially influences the bend solidness and the welding entrance. There are two fundamental types of the cathode top: tapered and round. In the principal case, the current thickness is a lot higher, so the current circular segment is concentrated, Fig. 85a. For another situation, current power is little, the circular segment isn’t concentrated, along these lines a lot of lower weld infiltration profundity and the more noteworthy width of the weld are accomplished, Fig. 85b. The conelike shape is utilized with DC and circular with AC, Fig.

86.

 Figure 85. The impact of the terminal top to the state of a seam  Figure 86.

2.5.3 Additional (filler) materials - welding wires

Wires for welding prepares (normalized by ISO 636) are regularly looking like poles length 1000mm, widths from 0.8 to 4 mm. In Tab. 19 are given information on certain wires for welding high-alloyed hardened steels from one of the manufacturers.

Table 19. Wires for welding stainless high-alloy steels

The

manufacturer's label (example)

TIG 19/9 Nb
TIG 19/12/3 Nb TIG 25/20
TIG 18/8/6

chemical composition (%) basic material C Si Mn Cr Ni Nb Mo USA AISI

AISI
AISI
AISI
AISI

9,5-10,5 9,5-10,5 301, 3040,07 0,6 1,9 20,5 0,8
0,8
0,8
0,8
0,8
0,8
0,8
0,8
3160,07 0,6 2,0 19,5 12,5 0,8 2,6
2,6
2,6
2,6
2,6
2,6
3140,12 0,7 1,9 25,5 21,0
21,0
21,0
21,0
21,0
8,0-9,0 high-alloyed 0,10 0,5 7,5 19,5 steel

For the welding of aluminum and its composites, wires and poles are utilized, Tab. 20. Their naming is characterized as follows: name of the item, d (xL), denoting the combination, condition of the composite, where d is the distance across and L is the length of wire (bar) in mm. An instance of marking is: Wire 2.0 S.AlMg3.20 - for drawn wire with a distance across of 2 mm, made from aluminum combination AlMg3.

Rods for welding aluminum and aluminum amalgams must be painted toward one side, on the brow, with a couple of shadings, Tab. 20. Use of wires and bars for welding aluminum and aluminum compound is likewise given in Table 20.

Table 20. The wires and rods for welding aluminum and aluminum alloys

marking paint color

S.Al99,8 blue-brown S.Al99,5 blue
S.AlMn1 purple S.AlMg3 green

S.AlMg5 green-brown S.AlSi12 brown
application (base material)
Al99,8; Al99,7
Al99,5; Al99; AlMn1 AlMn1
AlMg2; AlMg3; AlMg5
AlMg3; AlMg5
Al-Si alloys with Si> 8%

2.5.4 Shielding (defensive) gas and weapons (nozzles)

To secure the metal shower, the idle gases, argon or helium are utilized generally speaking. Essential benefits of argon contrasted with helium are higher ionization energy, which permits more straightforward building up and keeping up with the electric bend, lower voltage angle (6V) in the flow curve, which gives a unimportant change in voltage while changing the length of circular segment, articulated impact of cleaning oxides, less affectability to encompassing wind current, lower cost and safer work.

The upside of helium is a more noteworthy nuclear energy of the curve, which is fundamental in welding metals with high warm conductivity, particularly with a bigger thickness. An extra issue when utilizing helium is its low thickness (a few times lower than the air, while the thickness of argon is more prominent than the thickness of air), so to keep up with the defensive safeguard, gas stream should be two to multiple times higher. Thusly, by and by, most applied gas is argon and furthermore the combinations of argon with helium (for more noteworthy thickness or potentially materials with more prominent warm conductivity) or with hydrogen (Stainless steel).
Apart from the sort of the safeguarding gas, the spout shape hugely affects the viability of the insurance. Three essential types of spouts are utilized: tapered, barrel shaped and profiled, Fig. 87. The best security is accomplished by profiled (shaped) spouts. The gas supply to the spouts additionally influences the proficiency of insurance Fig. 88, which is completed with or without a support (cup). As displayed in Fig. 88, the cup has extremely beneficial outcome on the width of the security zone, and subsequently defensive efficacy.

Table 21. Shielding gases and their use according to EN 439 gas unalloyed or low alloy steels

Ar X
Ar + H2
He
He-Ar He-Ar
75)
He-Ar He-Ar
50)
weld root Forming pass gas
protection Ar/He
stainless steels

X X

Al Cu Ni Material sensitive to the gases

X X X X
X
X X X
X X X

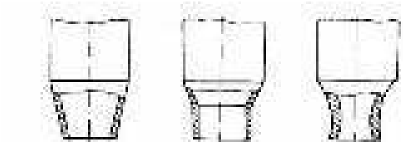
X X X

Forming gas
Ar/He-Ar Ar Ar Ar He

Table 22. The effects of shielding gas to the welding parameters

Gas Arc Arc Seam Weld Welding forming stability width depth speed Ar 3 3 3 2 2 Ar/He 3 3 2 2 3 He 1 1 1 3 3 He/Ar(25/75) 2 2 3 2 3 He/Ar(50/50) 1 1 2 3 3

1 - little influence; 2– medium influence; 3 - large influence



a. conical b. cylindrical c. profiled

Figure 87. The primary types of the nozzle

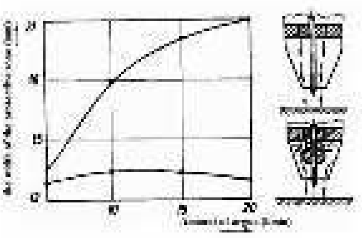


Figure 88. Impact of gas supply to the exit from the spout on the width of cradle zones

2.5.5 Welding device

The contraption for TIG welding is displayed in Fig. 89; its fundamental components are a power source, a jug (or containers) for a defensive gas, with suitable valves, burner with an insoluble anode, hoses bundle for argon supply, cooling water, and electrical cables.

The power source is for the most part with steeply plunging static attributes, as in MMA method to limit the irregular difference in the bend length from the electric flow power. Whenever provided by AC flow, the gadget should create an even or adjusted rushes of current.
Welding burner needs to have an adequate momentum limit all together not to overheat and generally is cooled via air or water. An essential piece of the burner is a spout, and spout shape fundamentally impacts the adequacy of security. The spout ought to have such a structure that the defensive gas flow has no disturbance, and that is as distant from the spot

of welding as conceivable so welder can have a superior view.

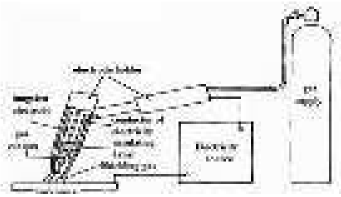


Figure 89. Plan of gadgets for TIG welding - essential elements

Supply hoses for safeguarding gas ought to be of an extraordinary plastic material, in the event that He is utilized, whose iotas are little that they diffuse through a standard elastic hose into the environment.

Likewise, gadget for TIG welding has the components for controlling force of the electric momentum, setting up curve without contacting the tip of the terminal on the workpiece, programmed opening and shutting of argon stream and cooling water, the HF generator and the condenser battery, and on account of TIG welding with a hot wire there is an extra component for wire obstruction heating.

2.5.6 Welding Technology

The fundamental boundaries of TIG welding technique are cathodes type and measurement, the sort and width of the wire, welding pace, type and force of the electric flow, just as the creation and the progression of the protecting gas. The impact of the decision of some essential boundaries (a kind of anodes, wires, and power, piece and stream of the safeguarding gas) has been now clarified. What’s more the impact of wire measurement, welding pace, and welding current power is practically as old as other bend welding processes. The effect of the cathode measurement is firmly identified with the material of which the anode is made, that is power (thickness) of power, like displayed in Fig. 84.

Interdependence of the cathode breadth, power and sort of power, and the kind of anode not set in stone based on information from Tab. 23. Choice of those welding boundaries for some primary materials is given in Tab. 24 (carbon prepares), Tab. 25 (low compound prepares) Tab. 26 (high-alloyed prepares) and Tab. 27 (aluminum and its alloys).

Table 23. Dependence of the current power and type from the electrode type and diameter
electrode I (A), DCDP I (A), ACIP I (A), AC (symmetrical) W Wdiameter, All All electrode Th, W-Th

Wmm electrodes electrodes Zr (0,5%) 1,6 70-150 10-20 30-80 60-120 30-120 2,4 150-250 15-30 60-130 100-180 60-180

60-180

3,2 250-400 25-40 100-180 160-250 250
250
4,0 400-500 40-55 160-240 200-320 320
320
4,8 500-750 55-80 190-300 290-390 390
390
6,4 750-1000 80-125 250-400 340-525 525 Abbreviations: DCDP – direct current with direct extremity, DCIP - direct current with circuitous extremity, AC– exchanging current

Table 24. Parameters of TIG welding for carbon steel
Workpiece thickness (mm)

0,5

0,8
1,0
Electrode diameter (mm)
1,6
1,6
1,6
Wire Welding Current Argon diameter Speed power flow
(mm) (cm/min) (A) (l/min)
- 15-25 15-30 4
- 30-40 35-50 4 0,8 30-50 35-60 4
1,2 1,6 1,2 40-80 50-80 4
1,5 1,6 1,2 50-100 70-100 5
2,0 3,2 1,2 70-120 80-120 5

Table 25. Parameters of TIG welding for low alloy steel

Workpiece thickness (mm)
3,0

4,0
5,0
6,0
8,0

10,0 Electrode Wire Welding Nozzle Current Argon
diameter diameter Speed diameter power flow

(mm) (mm) (cm/min) (mm) (A) (l/min) 1,6÷2,4 3,0 6 6 5

25-30 150
2,4 3,0-4,0 9 9 5 25 180
2,4-3,2 3,0÷4,0 20÷24 11 11 5-6 250
3,2 4,0÷5,0 18-20 11 or 13 11 or 13 6 340
3,2 5,0 15 13 13 7 340
4,0 5,0÷6,0 13 13-15 13-15 7 350

Table 26. Parameters of TIG welding for stainless steel

Workpiece thickness (mm)
0,6
1,0
2,0

3,0
4,0
5

6 Electrode Wire Current Gas Number Welding diameter diameter power flow of Speed

(mm) (mm) (A) (l/min) passes (cm/min) 1,0 no 15-25 3 1 30-40
1,0÷1,6 1,0÷1,5 25-80 4 1 25-30
1,6 1,5÷2 80-110 4 1 25-30
25-30

2,4 2÷3 150 4 1 25-30
25-30

2,4 3 200 5 1 25 25

3,2 3-4 250 5 1 25
25

3,2 4 250 6 2 25

Table 27. Parameters of TIG welding for aluminum and alloys WorkpieceNumber Wire Argon Current power (A) preheatin thickness of diameter flow)horizontalverticaloverheadtemperatu

(mm) passes (mm) (l/min (^{o}C)
1 1 2 7 60 50 40 -
2 1 2 to 3 7 80 80 75 -

3 1 3 8 140 135 130 -
4 1 to 2 3 to 4 9 180 170 160 -
6 2 3 to 4 10 280 240 230 -
8 2 4 to 5 12 320 270 260 150 10 2-3 5 14 360 280 270 200
12 3 6 16 420 330 280 200 15 5 6 16 450 - - 250 250
20 7 6 to 8 25 450 - - 350 30 9 8 20÷25 450 - - 350

2.5.7 Welding technique

The method of manual TIG welding methodology requires exceptional consideration, particularly when building up and finishing the circular segment and taking care of the welding wire and terminal. Curve can be set up in three ways: by contacting and moving away the terminal, by a flash from the extra gadgets (as a rule HF generator), and utilizing the helper circular segment set up between the cathode and the spout, and afterward moved to the base material. Commonly the most utilized are HF generators, and the primary way is being stayed away from, as it altogether harms the highest point of the terminal. Since the bend is set up, the light (burner) moves in little circles to shape the fluid metal shower, Fig. 90a with continuous tendency from the upward pivot by 15° in manual welding Fig. 90b,
while with the automatic welding torch remains in a vertical position. Then, the wire is added in the metal bath at an angle of 15°, Fig. 90c. Before moving the torch (electrode) to the front edge of the metal bath, Fig. 90e, the wire should be kept away, Fig. 90d. Repeating this procedure gives a continuous seam. The most effective way to end the arc is to turn off the power because suddenly moving away the electrode leads to oxidation of the weld metal seam. For positions that are not horizontal, the proper holding of the burner is shown in Fig. 91.

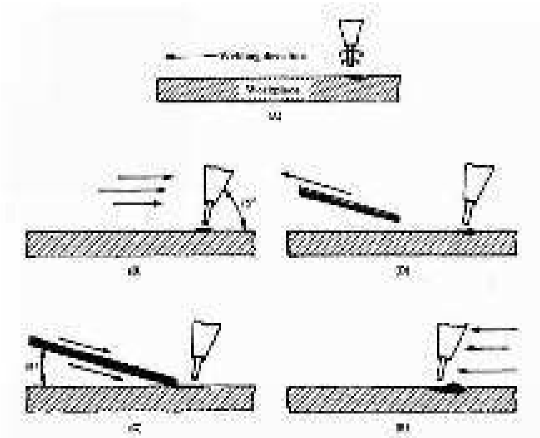


Figure 90. The method of manual TIG welding procedure

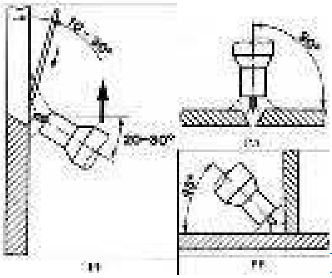


Figure 91. The strategy of manual TIG welding in forced positions

Failure to follow the prescribed technology and welding technique causes errors. The most common causes of errors are: too long arc, too big angle of the burner, torch moved from the weld joint axis, pulling the top of the molten filler metal (wire) from the weld melt protection zone and the like. The most common working errors are shown in the Fig. 92.

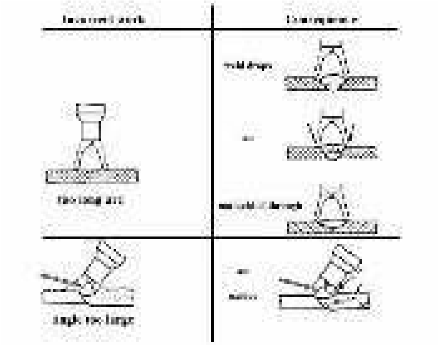
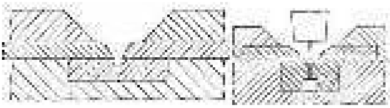


Figure 92. Resistance with the recommended welding strategies and the relating errors

2.5.8 Protection of weld root pass

For the top nature of welded joints, additional assurance of the root pass from the opposite side is required. Assurance of the roots is normally done with argon or framing gas (Ar + 1-30%H2, or N2 + 1-30% H2). Contraption for the security of the roots are displayed in Figure 93, and for the line root pass welding in Figure 94. When welding root passes of responsive materials, all zones of the base material which is warmed to a temperature over 300°C should also be ensured, ie. chamber with controlled climate (Ar), Fig. 95.



copper cushion - gathered a defensive gas, unsafe
additional defensive gas from the inverse side

Figure 93. Frameworks for root protection

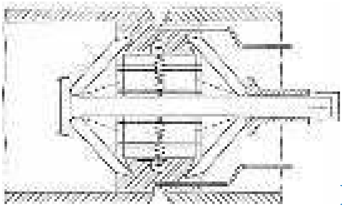


Figure 94. The arrangement of root pass assurance when welding pipes

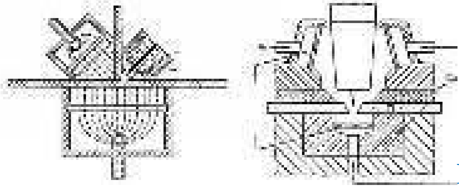
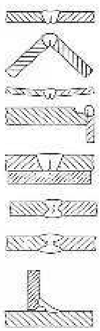


Figure 95. The arrangement of root pass assurance when welding of receptive materials

Among the most well-known missteps in welding are oxide considerations which unfavorably influence mechanical properties of welded joints. Figure 96 gives an outline of the most widely recognized reasons for oxide inclusions.

Oxide inclusions Causes Untreated groove
Too big groove - access of the air from the opposite side

Small groove opening Insufficient electric current



power for welding
Too long arc

Filler metal rod is too immersed in the bath
Oxides can’t be removed in the direction of the root

The effect of cathode cleaning is insufficient
(Not recommended for welding Al)

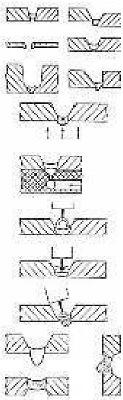
Too big thickness of „I“ joint

Insufficient amperage for welding
Excessive welding speed

There is no contact between the two workpieces
Insufficient current power of the welding, too long arc

Figure 96. The oxide inclusions and causes of their occurrence

Root welding requires uncommon preparing for welders on the grounds that the root is the zone with the most possible blunders. Normal mistakes in the root are displayed in Figure 97.



Too small opening angle of the groove
Staggered edges of workpiece

Too much or too little leeway in the root
Asymmetric gap
The oxidation from the air oxygen
Too much tension of the defensive gas in the root
Too long arc
Insoluble cathode with impurities
Too high amperage (Too little welding speed) Figure 97. Ordinary mistakes of root pass TIG welding

2.5.9 The modified variants of TIG welding

There is a wide assortment of adjusted TIG process, of which the most normally utilized are beat welding, welding in a restricted depression, orbital line welding, welding with a hot wire, spot welding, welding with double insurance, ATIG procedure.

Pulse TIG welding permits ideal utilization of energy on the grounds that the electric flow power increments fundamentally just in a brief timeframe when softened top of extra metal are isolated and moved into the metal shower. Beat TIG welding is entirely appropriate for programmed (orbital) welding of pipes.

Figure 98. Pipe butt joint with TIG process

Pipe butt joints, performed by TIG process, Fig. 98, requires an exceptional power hotspot for beat welding. Beating current starts with the foundation of the curve, yet the gadget doesn't turn around the line until the beat current working level is reached. At this stage groove is filled until the weld is thoroughly completed, then the device begins to rotate around the pipe. Prior to winding down the curve, ebb and flow power is diminished evenly to the underlying period of welding, and gadget is moving until complete cross-over of the
start of the crease is achieved.

TIG spot welding, likewise called TIG riveting, empowers making of a joint by covering, without past holes of the workpiece. The method is exceptionally basic and doesn't need extraordinary gifted administrators, it is extremely useful and can be robotized. Curve isn't noticeable, so the man administrator doesn't need to secure his eyes during

welding. The strategy is material to low alloyed prepares, aluminum, thickness from 0.5 to 2 mm. Welding time is from
0.5 to 5 s.

TIG welding with hot wire requires radiator, which preheats welding wire by the electrical opposition, accordingly permits quicker dissolving of the filler metal and better efficiency of the interaction, Fig. 99.

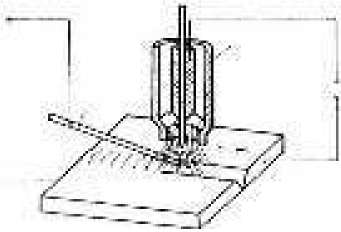


Figure 99. Welding with warmed wire

ATIG welding is a technique created at the Institute of Welding "Paton" (Kiev-Ukraine). The methodology is as old as TIG, with the stipulation that the edges of the section are plunged (spread) in the enactment of the motion prior to welding, this permits altogether more prominent profundity of weld and little granular design of the material stitch (crease). Actuation motions are applied in a splash, or with a pen expected for applying transition, or brush or in another reasonable manner. Expanded welding profundity empowers butt welding of plates with a level "I" groove, no hole, no additional material, for a thickness from 10 to 12 mm. This methodology is significantly more prudent than an ordinary TIG process.

2.5.10. Setting the machine for TIG welding

Welding machines are outfitted with a control board from which you can change welding boundaries. For legitimate execution of the interaction, on the cutting edge apparatuses we can set around ten boundaries that fundamentally influence the nature of the exhibition of the welding system. Other than the norm, there are synergistic and advanced machines in which welding boundaries are characterized by the program for the particular welding materials. With cooperative energy machines, beginning the particular program calls the characterized boundary comparing to the given material, thickness and position. Such gadgets are overseen by the processor and they can store a wide range of projects in the memory. Figure 100 gives model portrayal of some control board for computerized TIG (VARTIG 3500 AC/DC digits), with a clarification of the singular keys work. (Various producers will have diverse control sheets, and you will forever need to follow the first client manual for that device).

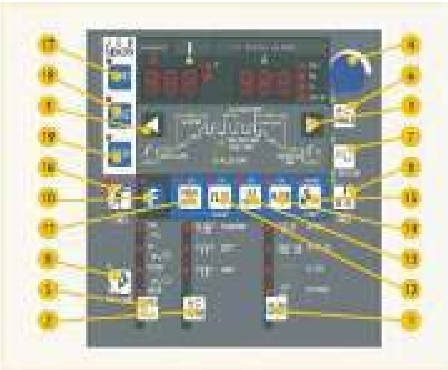


Figure 100. Appearance of the control board for TIG welding process contraption with stored programs (VARTIG 3500 AC/DC digit)

1. Selection of the welding system (AC - for Aluminum, beat - for top notch welds, DC - amended momentum for TIG, Corrected ebb and flow DC for bend welding)

2. The capacity of AC-WAVE, the determination of a heartbeat type.
3. Selection of welding boundaries (beginning flow, time for pre-blowing gas, upper and lower power beat, etc.)
4. An encoder for setting parameters.
5. Key for choosing working mode (spot or continuous)
6. Setting up the AC frequency
7. Setting AC total (aluminum welding)
8. Start of AC/DC TIG welding
9. Adjusting time for spot welding
10. Functional adapting to inside functions
11. Setting the underlying flow
12. Start of heartbeat welding
13. The strategy for building up arc
14. Button to change the addition and decrement of the flow
15. Election of a water-cooled torch
16. Controlling the progression of gas
17. Calling (stacking) the put away programs
18. Program stockpiling (saving) with the given boundaries (max. 100 programs)
19. Confirmation of putting away (saving)

2.6 Plasma arc welding (PAW)

Plasma is ionized matter that communicates power. It is a matter from which the bend is made of, for each circular segment welding process, regardless of whether noticeable all around or in a defensive gas. Various gases are more straightforward or more hard to ionize, this decides their materialness in welding systems. The temperature of the ionized gas circular segment is around 10 000oC. Plasma circular segment, in contrast with the MIG or TIG bend, is a lot more sweltering, denser and stiffer, which is accomplished by choosing the fitting gas and by the pressure (concentrating) of the arc.

Plasma curve welding is basically the same as TIG strategy. The primary contrasts between the TIG interaction and plasma welding system are looking like spout flies, the anode handle and the type of the plasma circular segment that goes through it. Burners for plasma welding can be made in the manner that the electric circular segment is set up between the base metal and tungsten (insoluble) anodes, making the supposed compact (adaptable) curve (Fig.101 a) or between the limiting spout and the tungsten (insoluble) terminal, forming
alleged non-adaptable bend (Fig. 101 b). Compact circular segments produce profound through welds in the base material and non-adaptable bends produce shallow welds in the base material. The non-adaptable circular segment can be utilized for welding material that doesn’t lead electricity.

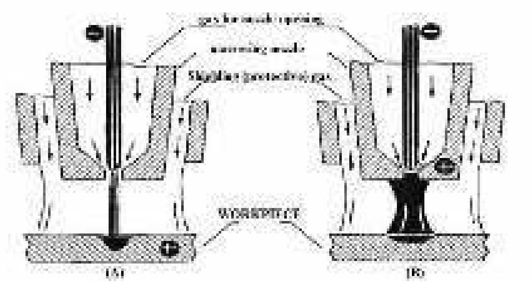


Figure 101. Burners for plasma strategies (A) Portable circular segment (B) Nontransferable arc

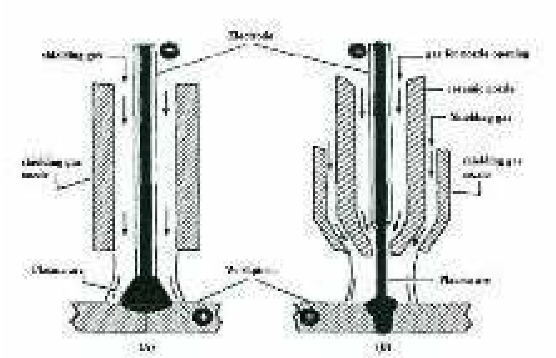


Figure 102. Examination of techniques (A) tungsten cathode curve in idle gas and (B) plasma welding arc

In TIG process the circular segment is free, while in the plasma bend welding (particularly at plasma cutting) curve is extremely tight (Fig. 102). In the plasma welding process, we have expanded length of the curve contrasted with the TIG bend. Plasma curve likewise has a round and hollow shape, while the chime state of the bend can be found in the TIG process.

Similarly to TIG technique, burners for plasma welding and plasma cutting are utilized with traditional wellsprings of power that have steeply dropping qualities (direct current direct extremity). Traditional TIG power sources can be utilized for plasma welding basically adding a control box that manages the curve foundation, the progression of gases and cooling water. Plasma cutting requires a similar essential power source type, notwithstanding should have a lot higher voltage inactive burden and ought to have the option to deliver a lot higher amperage than TIG power source. Open circuit voltage of the plasma unit can be high up to 400V. Truly, practically any wellspring of direct current with steeply plunging voltage and the most reduced worth of the voltage inactive heap of 80 V and the primary contactor can be utilized for the activity of the gear for plasma curve welding. Least current you will accomplish relies upon the power source. Most ordinarily, however, the high voltage is given by uncommonly planned power hotspots for the plasma arc.

Advantages of plasma welding contrasted with the typical TIG welding are:
- The further developed inflexibility of the plasma circular segment permits simpler control of hotness input into the workpiece.
- The more prominent length of the bend according to the TIG cycle permits the less issues in keeping up with the right place of the burner.
- The size of the weld pool (shower) in the utilization of plasma is likewise less touchy to changes in the length of the arc.
- It is more straightforward to present extra wire or pole and to control the burner handle because of higher distance between the spout and the workpiece (5 - 12 mm).
- Additional wire or bar of bigger measurement can be utilized with negligible danger of contaminating the weld metal. This is especially significant in the welding of hardened steels, aluminum, and titanium.
- Because the plasma circular segment is more sizzling than the TIG curve, welding speeds are higher, and heat impacted zone is narrower.
- Plasma welding process is less touchy to the mathematical incongruence of the joint and terrible fitting of the joint than the TIG interaction. The primary reasons are higher entered heat, because of that the plasma bend welding is handily robotized. Notwithstanding these benefits, there are inconveniences to the plasma welding process, namely:
- Equipment for plasma circular segment welding costs more than practically

any other
welding strategy by bend or opposition.
- Clay spouts toward the finish of the light have a short help life because of exceptionally high temperature of the plasma arc.
- Consumption of moderately costly idle gas is additionally higher in light of the fact that it is utilized for molding the plasma circular segment just as for protection.

2.6.1 Welding plasma technique

Welding procedures that are utilized with manual plasma process are like those utilized in TIG welding. Because of the more prominent bend length, there is no danger of contamination to the workpiece by means of contact of tungsten terminals with workpiece, or tungsten contamination from the metal crease. The space for the acquaintance of extra wires with the bend and to the welding shower is bigger. There are two unique methods of drenched (lowered, puddle) and keyhole technique.

Most manual plasma welding processes are through puddle (frequently alluded to as procedures of suffocating), which just implies that welding:

welding the extra wire is presented in the liquid shower crease or close to the plasma curve, same similarly as with TIG light. It is basically the same as the manner in which you would work the wire in oxy-gas flames.

Another method of plasma welding that you can utilize is the keyhole strategy. Keyhole welding is utilized for flimsy segments like slim sheets and strips, as a rule without the utilization of extra wires. Notwithstanding, the materials with a thickness up to 6mm can be welded by keyhole method through different settings for electric flow power and circular segment voltage. An illustration of keyhole welding strategy use is making creases on the corner, on the flanged and lapped stitches for interfacing two bits of dainty metal sheets.

To begin a crease by the keyhole method, the light is stood firm on in practically vertical situation. Then, increase the current to the working value. The burner isn't moving until a keyhole is made through the workpiece. When the keyhole is framed in one piece, welder can start to move burner to make a consistent crease by softening. The most basic piece of the weld acquired by utilizing manual keyhole strategy is at first hole of the workpiece. During this time burner light ought to be held opposite to the workpiece.
Plasma bends ought to be coordinated straightforwardly to the base material. In the event that the burner isn't opposite to the workpiece, the return plasma sprinkle can cause breaking of the light spout, because of high warm pressure. Additionally, you want to offer a higher benefit of gas stream for the plasma framing than for the welding strategy for drowning.

When the finish of the crease is reached, keyhole is shut by bringing down the welding current to diminish the hotness in the workpiece, and simultaneously decrease the progression of the gas for shaping plasma. Both of these methods, acting together, will lessen the hotness in the keyhole permitting remained crease shower to enlarge and fill the keyhole.

3. THERMAL CUTTING (groove edges

preparation)

Creating groove edges ordinarily is finished by warm cutting. There are a few strategies for warm cutting, and the most usually utilized are gas cutting, electric curve or plasma cutting, that are like the fitting welding procedures.

3.1 Gas cutting

Gas cutting is a course of isolating metal by its burning in a surge of oxygen, while extinguishing the ignition items (slag), Fig. 103. To perform metal burning, it ought to be preheated to a temperature of start (beginning of ignition). Gas slicing of the metals has a place with the warm cycles, by which the functioning temperature is accomplished by ignition of the flammable gas (acetylene). What's more, ignition of the fuel gas gives the piece of the hotness by which the working temperature is kept up with, and critical piece of the hotness is acquired by consuming the metal for cutting (fire cutting), and this is a huge benefit of this cycle. Since the gas cutting depends on the burning of metals, there are sure conditions that should be met all together for the slicing to take place:
- Combustion temperature of the metal ought to be lower than the softening temperature.
- The dissolving temperature of the oxide ought to be lower than the liquefying temperature of the metal.
- The ignition hotness of metal ought to be adequate, along with the fieriness of the fire, to keep up with the temperature of combustion.

From development materials, these conditions are most appropriate to low carbon steel. Ignition temperature of carbon steel relies upon its organization and is moving toward dissolving temperature with the increment of the carbon content Fig. 104.

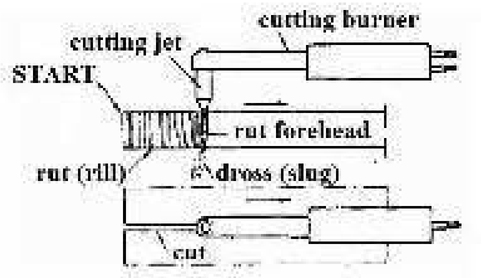


Figure 103. Schematic of gas cutting

Combustion (burnout) of steel can be introduced by the accompanying substance equations:

Fe+0,5O2=FeO+267 kJ
2Fe+1,5O2=Fe2O3+825 kJ
3Fe+2O2=Fe3O4+1120 kJ

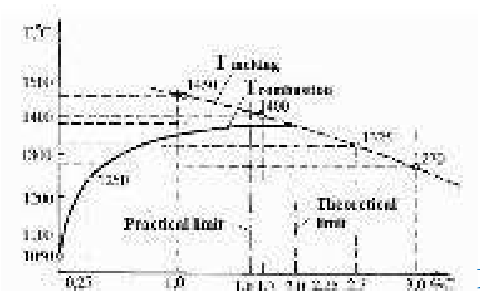


Figure 104. Change of the ignition temperature and the liquefying temperature of steel

The delivered heat makes around 2/3 of the hotness required for burning of the steel and 1/3 is gotten by the ignition of flammable gas (fuel). It ought to likewise be noticed that

FeO and Fe2O3 proceed to respond and the end result of burning is Fe3O4, which as slag is extinguished from the cutting spot, Fig. 106.

3.1.1 The device for gas cutting

The hand-held gas cutting gadget is fundamentally as old as gadget for gas welding, given that the burner is unique, so we will just depict the burner, exhaustively. The spout is basic for effective cutting, and they can be extremely assorted and custom-made to the particular prerequisites (spouts for various fuel gases, for various thicknesses, for quick and slow cutting, for extraordinary conditions). Practically speaking, motorized and programmed cutting are regularly utilized, which requires the establishment of extra parts of the unit.

Since the amount of heat that is used in the cutting process (2/3 from the combustion of metal, a third of the fuel gas) it can be considered that the main role of the fuel gas is to heat the metal, and start the process of combustion, which then takes place in an independent stream of oxygen. Consequently, the development of the cutting light is more muddled than the light for welding, Fig. 105, albeit a few sections are something very similar, for instance, the burner holder (handle). The principle distinction is in the lines that give fuel combination supply of gas and oxygen and the free inventory of oxygen for burning, and in the spout structure which needs to give gases spillage similarly. In this way, the cutting burner comprises of lines for gas blend inlet,

Fig. 105, pipe with pass valve for oxygen supply and a spout with a focal gap for oxygen and fringe openings (or ring opening) for the
mixture.

Burner for hand cutting has just two entry openings (oxygen and acetylene), which implies that a similar oxygen is utilized for ignition of the acetylene and for cutting the metal. Albeit the hand burner is outfitted with three free valves, the delivering the fly for cutting actually causes the problem in acetylene fire, so its definitive control is performed later the arrival of oxygen fly. This inadequacy is redressed at the burner for machine cutting, in which there are two free stock gulfs for oxygen.

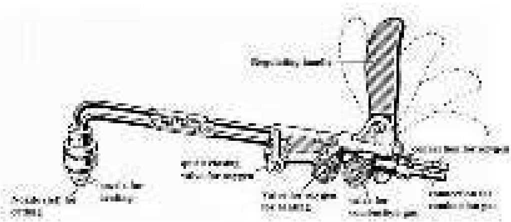


Figure 105. Burner for gas cutting

Two fundamental variations of the spout (the ringed-annulus or numerous openings for blend supply) are shown in Fig. 106. The annular gap is utilized just when you want a lot of heat.

The state of focal oxygen supply port is generally tube shaped or conelike, Fig.
107. The round and hollow shape is more straightforward to make and keep up with, yet the progression of oxygen is to some degree mistaken Fig. 107a. The tapered shape gives a uniform current of oxygen, yet it additionally would not give great outcomes in cutting items with greater thickness. For this situation, streamlined state of the focal gap can be applied, Fig. 108, which brings about more noteworthy stream speed of oxygen and the most effective cutting. Inadequacies of these planes are significant expenses in light of the muddled assembling and making a great deal of

commotion. The standard spouts with a tube shaped focal gap are created in different sizes, contingent upon the thickness of material Tab. 28.

Table 28. Standard nozzles for cutting

external 1 2 3 4(number)

internal 1-2 3-4 5 6(number)

material 3 ÷ 10 / 10 30 ÷ 60 / 60 100 ÷ 200 200 ÷ 300thickness (mm) ÷ 30 ÷ 100

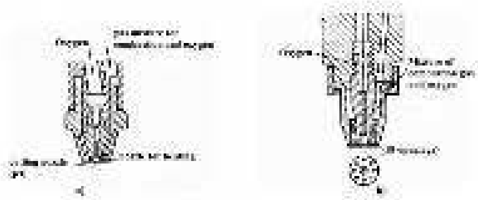


Figure 106. Spout for cutting (a) with an annular opening (b) with a majority of openings

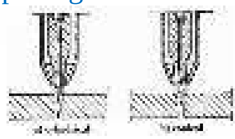


Figure 107. Spouts with various openings

Figure 108. The streamlined nozzle

With hand-held light there is plausible of applying extra components (devices) to give a stable situation, bringing about a motorized cutting. Fig. 109, highlights three variations of extra instruments, whose job can be a rectilinear directing of the burner (variations An and B, with that in the variation B forefronts are calculated) or a directing of the light naturally form, variation C.

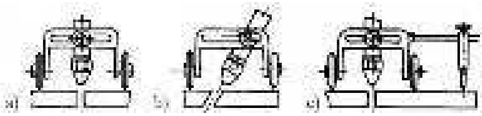


Figure 109. Extra burner light instrument (“carriage”) for motorized cutting

Automatic cutting requires muddled and costly machines, which are savvy just for sequential monstrous creation. Machines for cutting can be portable or ardent. Portable machines are basically utilized for straight slicing however can be adjusted to discretionary curvilinear development (cutting), Fig. 110.

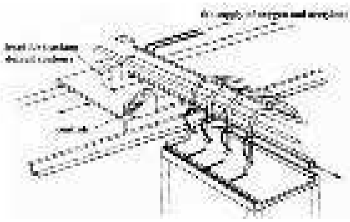


Figure 110. Plan of gas cutting machines

3.1.2 Technology gas cuts

Gas removing is conveyed in a few phases:
- Metal is first preheated by acetylene fire until it arrives at start temperatures (beginning of ignition), which for the steel is 1300 ÷ 1350 °C.

- For ignition of copying metal, the stream of oxygen is coordinated on the preheated place, where the speed and stream of the fly are controlled by the thickness of the material.

- When on the beginning spot for cutting, the whole thickness is ‘crushed’ (overpowered), the light is moved with the speed which permits consistent contact between the oxygen shower and the slag.

The legitimate cutting interaction happens at a steady rate with constant splash of burning items (oxides as a sparkle). In this acetylene fire and metal burning ought to give adequate hotness that the upper edge of the cut is continually at start temperature. With cutting metal sheets, process is somewhat basic, however when cutting profiles, pipes and different articles with more confounded segment, uncommon procedures are applied all together not to make distortions and lingering stresses. Fig. 111a shows the strategy (the request for) cutting the square profile. In Fig. 111b, and Fig. 111c
are shown great and terrible procedure of cutting a round profile. In addition, to reduce the thermal deformation when cutting, start, stop and order of the cuts must be properly chosen, Fig. 112.


Figure 111. Instances of cutting a square and round profiles

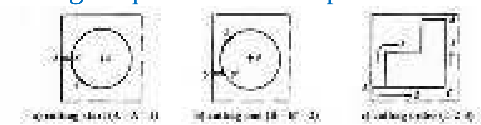


Figure 112. The ideal decision of the beginning, end and the request for cutting

The fundamental boundaries of the gas cutting are the stream and tension of oxygen for ignition and cutting velocity. These boundaries are chosen by the thickness of the material, despite the fact that there is additionally their reliance. The progression of oxygen for burning is managed by the distance across (number) of the spout, which is picked dependent on the material thickness. The strain of ignition oxygen fundamentally influences the solidness of the cutting system, so exceptional consideration ought to be given to its assurance and upkeep during the cutting. Cutting velocity affects the right oxygen spillage at the base edge of the cut and support of a consistent cutting temperature. Notwithstanding the thickness, cutting rate relies upon the size of the spout and the underlying temperature of cutting. Cutting rate can be restricted by the event of avoidance of the ignition items stream at the cut surface, Fig. 113 (diversion is corresponding to speed). The diversion has no huge effect on the nature of cutting assuming that its worth is inside the restrictions of 5-15% of the thickness of material, however with higher redirection, the cutting rate should be reduced.

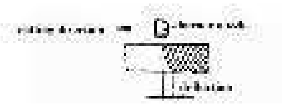


Figure 113. The avoidance of the items burning stream (jet)

3.1.3 The cutting of various materials

From development materials, the steel (low carbon and low alloyed) has the best prerequisites for gas cutting. In doing as such, the standard is that cutting is simpler as there is less carbon in the steel in light of the fact that the increment in carbon content lessens the distinction between the burning temperature and the softening temperature, Fig. 107. Gas cutting has no critical effect on the properties of low carbon steel, while on account of the steel with a higher carbon content, the peculiarity of solidified layer around the edges of the cut (heat impacted zone) can be taken note. The profundity of this zone is given in Table 29, contingent upon the thickness and the kind of material.

Table 29. The depth of heat affected zone for a gas-flame cutting of steel

steel the depth of the heat affected zone (mm) sheet thickness 5 25 100 150 300 (mm)

low carbon 0.1 ÷ 0.5 ÷ 0.7 1.5 ÷ 2.0 1.5 ÷ 3.0 4.0 ÷ 6.0

0.3

medium carbon 0.3 ÷ 0.8 ÷ 1.2 2.5 ÷ 3.0 3.5 ÷ 4.3 6.0 ÷ 7.0

0.4

high carbon 0.4 ÷ 1.2 ÷ 1.5 3.0 ÷ 3.5 4.3 ÷ 5.0 7.0 ÷ 8.0

0.5

Alloy steel can be gas cut, however it ordinarily needs preheating and ensuing hotness treatment. Investigation of the impact of alloying components on the chance of cutting steel is given in Table 30, noticing that it manages the singular effects. Phosphorus and sulfur in sums standard in the steel, have no impact on the cutting.

Table 30. Limit values for the content of alloying elements Alloying Si Mn Cr Ni W Mo V Cu element (%)

no problem <2 <14 <1.5 <25 C <10 <1 <3 <2

<0.7

preheating <4, C <18 C <5 <40 C <20 <2 * <0.4 * <1.5 <0.3

impossible > 4 > 18 > 5 > 2.5 * For very slowly cutting

The singular impacts of alloying components are fundamental to examine the opportunities for cutting composite steel, yet a lot more noteworthy is the reasonable significance of their shared impact. Subsequently, the chance of cutting steel with the gas interaction is assessed based on its compound piece, utilizing the term by which the impact of alloying components are addressed as the same effect of carbon (as in evaluating the weldability):

CE = C+0,4 Cr+0,3 (Si+Mo)+0,2 V+0,06 Mn+0,04 (Ni+Cu)
Taking into account the CE, just as the substance of carbon, prepares can be · · · · · named displayed in Table 31.

Table 31. Classification of steel according to the possibility for gas cutting

Group CE (%) C (%) Cutting conditions
I up to 0.6 to 0.3 Cutting very good, heat treatment

unnecessary

II 0.6 ~ 0.8 to 0.5 Cutting satisfactory. Preheating required for thicker workpieces and low ambient temperature

III 0.8 ÷ 1.1 to 0.8 Cutting will be difficult because of hardenability and tendency to crack. Preheating is necessary.

IV over 1.1 Over 0.8 Cutting is preheating cutting. very difficult. Necessary and lightly cooling after

The impact of alloying components on cutting steel and cast iron is given below.

Carbon (C)
Steels up to 0.30% C can be cut with practically no trouble. Steel with a higher
content of C can be sliced assuming it is preheated to 300-500ºC. Graphite and cementite forestall slicing and cast iron up to 4% carbon can be cut assuming it applies uncommon work technique.
Manganese (Mn)
Steel with 14% Mn and up to 1.5% C (austenitic manganese

steel) should be preheated.

Silicon (Si)
In ordinary sums (up to 0.35%) isn't a deterrent to cutting. Transformer iron containing up to 4% Si is additionally cut. Silicon steel containing high measures of C and Mn should be preheated, and consequently strengthened to try not to solidify noticeable all around and surface cracks.

Chromium (Cr)
Above 5% Cr requires preheating and special work technique, but by and by cut is fairly unpleasant looking. It is important to preheat.

Nickel (Ni)
Up to 30%, Ni doesn't forestall cutting and fine cuts are accomplished in steel containing Ni up to 7%.

Molybdenum (Mo)
It works similarly as Cr. Mo-W prepares can be cut distinctly with unique techniques.

Tungsten (W)
At a pace of 12-14% W doesn't make it hard to cut and restrict for the effective cut is 20%.

Copper (Cu)
The sums up to 2% don't represent any trouble for cutting.
Aluminum (Al)
In amounts, up to 10% doesn't influence the capacity to cut.

Sulfur (S)
The amounts normal for primary prepares up to 0.06%, don't influence badly the opportunities for cutting. In bigger amounts, it eases back cutting and creates critical amounts of desolate vapors.

Vanadium (V)
In limited quantities (up to 1.5%) further develops cutting ability.

Cutting cast iron
High carbon content in the cast iron is an impediment to the standard procedure of gas cutting, applied to the low carbon prepares. Cast iron contains some carbon as graphite lamellae or knobs, and some as iron carbide Fe_3C. The two constituents forestall oxidation of iron. Top notch cuts accomplished when cutting steel, can't be accomplished with cast iron. Frequently, the slicing is acted to eliminate the projecting framework, imperfections, fix or redrawing of castings or for waste.
Larger spout and more prominent gas stream from that utilized for steel is needed for cutting a similar thickness of cast iron. Unnecessary progression of flammable gas helps in keeping up with preheat during burning. Cast iron is likewise here and there cut by applying exceptional methods for cutting oxidation safe steel. These methods are an extra plate, cutting with the metal residue (powder) or utilization of compound flux.

3.1.4 Cutting metal powder

This strategy is reciprocal to the procedure of gas cutting with stream powder wealthy in iron. Powder material speeds up and works with oxidation and furthermore dissolving and splashing of the materials that are hard to cut. The powder is coordinated into the cut and through the spout tip, with at least one planes all through of the tip. While applying the primary strategy, the powder is placed into oxygen for slicing prior to terminating the gas through the spout tip. At the point when the powder is conveyed by outside ways, fuel gas gives powder particles enough speed to be moved through the preheated part in the flood of oxygen for cutting. This brief time frame in the preheated state is adequate to create an ideal response in the cutting zone.

Some piece of the powder synthetically responds with the unmanageable oxides delivered in the cut and expands their ease. The leftover liquid slag is washed with a fly of oxygen from the response zone. New metal surfaces are consistently presented to a fly of oxygen. The strategy is applied with a powder of iron and combinations of metal powders, like iron and aluminum.

Cutting steel impervious to oxidation from metal powder can be performed at about a similar speed as oxygen cutting of the carbon steel with comparable thickness. The progression of oxygen for slicing should be somewhat higher in the powder process.

3.1.5 Cutting using flux

The cycle is principally expected for cutting tempered steel. Motion is adjusted to respond with oxides of the alloying components like Cr and Ni and to create a compound with liquefying guide close toward the dissolving point of iron oxides. Requires the extraordinary mechanical assembly for addition of motion in the cut. With the expansion of transition, tempered steels can be cut in uniform straight velocities without light motions. Slicing speeds are drawing closer to expected qualities for a comparable thickness of carbon steel. The size of the spout tip will be bigger and the cutting oxygen stream will be somewhat higher than for carbon steel.

3.1.6 Special gas cutting techniques

Special strategies are essentially identified with the cutting of thick plates (north of 300 mm thick), stacked sheets, fluting and submerged cutting. The principle issues when slicing thicker sheets are to give an adequate measure of gas and satisfactory hardware. An adequate measure of gases (basically oxygen) is vital all together not to intrude on the most common way of cutting in light of the fact that proceeding with cut with the thick sheets is incredibly troublesome. Uncommon burners cut the thickness of the plates up to 1500 mm.

Cutting of the stacked sheets is regularly used to save time and gas, Fig. 114. As oxygen utilization isn't relative to the thickness of the sheet, it is clearly conceivable critical reserve funds by at the same time cutting a few slender sheets. This procedure is restricted to plates more slender than 13 mm in light of the fact that the
thicker plates are difficult to fix in one position. Cutting stacked sheets are

also used for very thin sheets that individually may not be cut. The total thickness of the stack of sheets is limited by the given cutting tolerance. For practical purposes, the total thickness of the stack of sheets should not exceed 150 mm. If the total thickness is small, the additional plate can be used which is placed above and whose role is to prevent warping and to provide a good start of cutting. When cutting the stack of plates, there are two basic problems. The first of them is connected to the start of the cutting and the other for maintaining the cutting process. To ensure a good start of cutting, several techniques are used. The simplest one is folding sheets with the shearing of the sheets beginning so that cutting starts from the top sheet and is transferred gradually through all the sheets. Maintenance of the cutting process can be affected by the layers of air between the sheets. One of the options to prevent the influence of air on the process of cutting is the use of nozzles for high flow rates.

Figure 114. The cutting of stacked sheets

Grooving (groundwork for welding) is a typical utilization of the gas cutting, particularly for thicker sheets. For this work, standard burners are utilized, and by the standard, it is a motorized, Fig. 115. The places of the burner for the three most normal types of the depression (V, X, and twofold Y) are displayed in Fig.
116. Sizes set apart with An and B, which characterize the place of the burner, rely upon the plate thickness, the size of the spout and the cutting rate. Some unacceptable situating of chosen burner brings about critical mistakes in making grooves. Keeping the position is similarly significant, notwithstanding, so machines are utilized For making grooves, or automated cutting. For
submerged cutting an altered plan of the light with an extra channel for packed air is utilized Fig. 117. The job of the air is to seclude the area of cutting from the encompassing water, which gives working conditions as a conventional gas cutting, and to balance out the acetylene fire for preheating. Burner for submerged cutting can have extra gadgets for the development of air bubbles and for holding (fixing) the

working position.

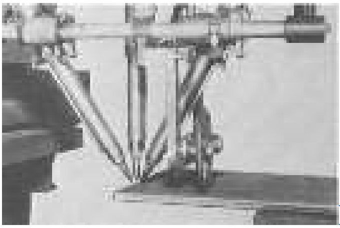


Figure 115. Automated notch production

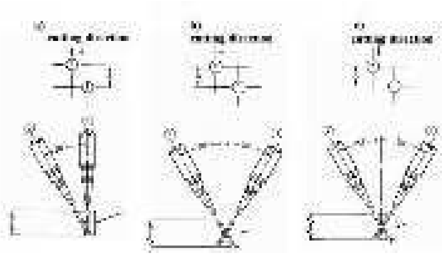


Figure 116. Places of the burner in the arrangement of
a) V-groove; b) X notch; c) Double Y-groove


Figure 117. Plan of burner for submerged cutting

3.1.7 Faults in the gas cutting

Due to wrong chosen boundaries or resistance with the recommended innovation, bring about different kinds of imperfections in gas cutting. The most widely recognized blunders are displayed in Fig. 118. When in doubt, these mistakes can be amended by resulting machining treatment.

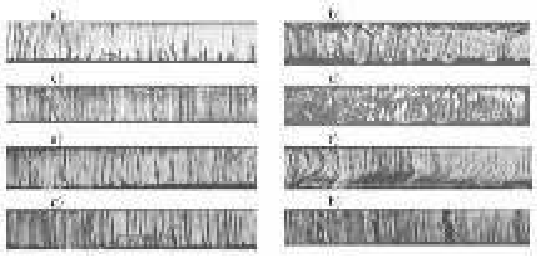


Figure 118. Cutting errors:
a) lacking preheating and cutting pace, b) too long preheating flame, c) deficient oxygen pressure, d) too high oxygen tension and little spout opening, e) inadequate cutting rate, f) over the top cutting pace, g) changing cutting velocity, h) awful continuing

3.2 Arc cutting

Arc cutting depends on the softening of metals and blowing melt from the drain, utilizing oxygen or compressed air. As the curve temperature is adequate to soften every single business metal, this strategy has less limitations than gas slicing as far as materialness to different materials. There are many circular segment cutting varieties, and the most normally utilized are graphite or empty electrode.

Arc cutting and gouging (scoring), by the empty terminal through which streams a flood of oxygen (OXYARC system) utilizes the curve hotness to melt
metal and compressed oxygen for his victory and fractional burning. The interaction is modest and simple and can be applied to a wide range of steel, cast iron and non-ferrous amalgam, and is usually utilized for fixing harmed parts. The cut surface region isn't adequate and is liable for the execution of vital extra machining.

Arc cutting and gouging with graphite anode (ARC-AIR technique) utilizes curve hotness to soften metal and the air moving through the two openings on the cathode handle for the liquefy victory. As in the past case, the interaction is basic and modest, however the nature of the cutting surface is terrible. The fundamental utilization of this system is for gouging in situations where ordinary methods can’t be utilized. Instances of ARC-AIR process applications for creation of U and twofold U-groove are displayed in Fig. 119, and the use of the gouging root weld (4 distinct situations) in Fig. 120.

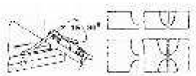


Figure 119. Making the notch with ARC-AIR procedure

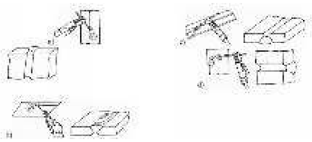


Figure 120. Scoring with ARC-AIR process in various positions:

a) vertical; b) the overhead; c) even; d) on a level plane vertical

3.3 Plasma cutting

Cutting with plasma circular segment is basically the same as the course of plasma welding, the thing that matters is in the construction of the light head for cutting and a lot higher voltage supply.

When cutting by plasma, high-temperature plasma bend dissolves the workpiece, and the soften is extinguishing of the cut by dynamic energy of gas, which emerges from the spout. Cutting is normally performed by the plasmatron with adaptable bend, by which all electrically conductive materials can be cut. Plasmatron with a non-adaptable bend is utilized for cutting the object of little thickness (under 1 mm), and electrically nonconductive materials (eg. Ceramic). Regardless anodes of tungsten compound are used.

To date, various techniques for plasma cutting are grown, like the utilization of compacted air as a gas for plasma, utilization of two free gases one as working gas and the other as a defensive gas (Fig. 121 a), water infusion for more productive limiting of the curve (Fig. 124 b). Cutting is typically utilized with following plasma gases:
a) a combination of Ar and H2 in the proportion of 60: 40%, which primary elements are high slicing power because of the great warm conductivity of H2, the parallelism of the cut and marginally raised edges of the cut. b) A combination of Ar, H2, and N2 in a proportion of 60: 20: 20%, where the expansion of N2 diminishes the harshness of the cutting surface, however at the slacking of the notch edges, and the cut surfaces are not metal pure. c) A combination of Ar and N2 in the scope of 50: half, which empowers higher cutting speeds.

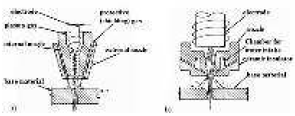


Figure 121. The fresher strategies of plasma cutting a) with two autonomous gases; b) with water injection;

3.3.1 Application procedure

Cutting with plasma bend can be utilized for cutting all metals. For the most part it is utilized for carbon steel, aluminum, and hardened steels, basically in light of the fact that they are the most well-known metals utilized. Be that as it may, plasma slicing process applies similarly well to any metal: copper, metal and bronze; Nickel and its combinations; metal zirconium and cutting uranium. Plasma cutting is utilized for cutting in parcels, sloping thick plates, area cutting and cutting openings. Plasma plays out these errands with less hotness input into the base material than oxy-gas fire (in spite of the fact that plasma is extremely hot), it is the consequence of quicker development of the plasma light than the light for oxy-gas fire and cutting component also (plasma dissolves and vanishes the metal and oxy-gas fire consumes metal). The consequence of plasma cutting has less misshapening of the base material.

Plasma cutting lights are utilized frequently on the machines for profile (cutting of various shapes) just as machines for cutting up and rectangular cutting at high paces. It requires next to no manual work since it includes high electric flow power and high inactive voltage load. The commotion level of fast plasma gas stream is likewise extremely high and the cycle can deliver a ton of stodgy metal fumes. The commotion and exhaust are undeniably challenging to take out when working with hand-held light. They are not an issue for programmed burner which can be mounted on an appropriate machine for fire cutting.

Fumes, hotness, and clamor created by plasma light can be effortlessly wiped out with the machine table for cutting, which is loaded up with water. The water is simply contacting the lower part of the sheet where it covers exhaust and slag. Water likewise hoses commotion made by fast plasma stream when leaving the burner head. With the plasma cycle, metals can be sliced at speeds from 2.5 to 4 m/min, while utilizing oxy-gas burner legitimate speed were from 0.5 to 0.7 m/min (substantial for lesser thickness). Velocities of up to 7 m/min are utilized when cutting meager materials. The administrator in manual work can barely adapt to the speed for the proficient activity of plasma light cutting. Thick metal sheets (north of 70 mm) of carbon steel can be cut quicker by oxy-gas process than by plasma. However, for profundity under 25 mm, plasma slicing is up to multiple times quicker than oxy-gas cutting cycle. On machines is normal that the plasma cutting lights are mounted along with oxy-gas burners, permitting quick progress from the oxy-gas slicing to the plasma cutting as well as the other way around, contingent upon whether the iron or non-ferrous material are cut, or regardless of whether thick or slight material are cut.

3.3.2 Power sources for plasma cutting

Electric flow hotspots for plasma cutting are explicitly planned units with the voltage esteems in the sitting scope of 120-400 V (contrasted with 70-85 V for the voltage sources expected for the circular segment welding). The decision of force source is performed dependent on the construction of plasma light to be utilized, the sort and thickness of the piece to be cut and cutting rate range. Direct current machines are utilized, which are portrayed by steady current with steeply diminishing voltage.

The plasma cutting interaction happens under direct extremity of direct current, with the cathode associated with the adverse terminal and with the limited, adaptable curve. In

troublesome cutting conditions, a high voltage esteem load of
400 V are needed for slicing through material thickness of 50 mm. Gear for manual plasma cutting of low current power utilizes a high voltage esteem inactive heap of 120-200 V. Such high voltages requires consistent thoughtfulness regarding the working faculty. The result current from the power hotspot for the plasma circular segment can go from 10 to 1000 A, contingent upon the material to be cut, its thickness and cutting pace. These power sources will likewise have circuits for helper bend and for shaping curve utilizing HF generator.

3.3.3 Modifications to the plasma cutting procedure

Several variations of the plasma slicing process are utilized to work on the nature of cuts. They are by and large appropriate to materials in the thickness range 3-40 mm. Additional assurance, as gas or water, is likewise used to work on the nature of cuts.

Cutting with twofold plasma flow

When cutting by twofold plasma stream, the second layer from various gas around the plasma bend is given, as displayed in Fig. 122. Normally, the gas for making plasma is the nitrogen. The decision of the security gas depends on the material to be cut. For delicate (gentle) steel it tends to be carbon dioxide or air and cutting velocity will be marginally higher than those for general cutting by plasma circular segment, however the nature of the cutting isn't palatable for all applications. Carbon dioxide is frequently utilized for insurance of hardened steels. Combinations of defensive gases argonhydrogen are utilized for aluminum.

Plasma cutting in water protection

This method is like cutting by twofold plasma stream. Water is utilized rather than the helper protecting gas. The presence of cut and spout lifetime are improved by the utilization of water as security. Symmetry of cut and cutting pace are not altogether worked on contrasted with the ordinary plasma cutting.

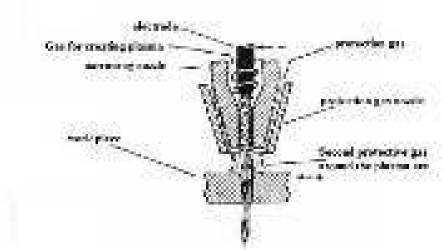


Figure 122. Cutting with twofold plasma flow.

Plasma cutting with water injection

In this plasma cutting change the evenly hitting water fly is utilized, close to the restricting spout opening for additional limiting of the plasma“fire”. The fundamental system of the activity is displayed in Fig. 123. The flood of water likewise shields the plasma from the tempestuous blending of the plasma with the encompassing air. The spout end can be made of earthenware production, which helps counteraction of duplication of the circular segment. Copy curve happens when the circular segment bounces from the cathode to the spout and afterward to the piece, and it generally demolishes the spout. Water contracted plasma produces
a limited, pointedly molded cut at speeds over those for the standard plasma cutting. Since the most measure of water is emerging from the spout as a fluid scattered stream, it cools the edges of the opening, creating sharp points. At the point when the gas for building up plasma and water are infused extraneously, the plasma-gas is whirled when it shows up

from the spout and water fly. This produces opposite regions with superior grade on one side of the opening. The opposite side of the opening is calculated. When utilizing the rectilinear cutting, the propelling heading of the burner should be chosen to deliver an opposite slice to the part, and an inclining slice to the waste.

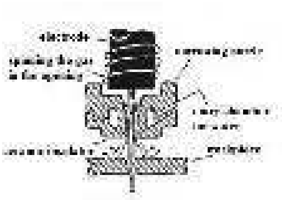


Figure. 123. Plasma curve cutting with the infusion of water.

3.3.4 Gases for creating plasma

The determination of gases for shaping plasma depend on the material to be cut and the necessary surface nature of the cut. Most non-ferrous metals are cut utilizing nitrogen or blends nitrogen-hydrogen or argon-hydrogen. Titanium and zirconium are cut by the unadulterated argon plasma on the grounds that these materials are very touchy to embrittlement brought about by dynamic gases, specifically hydrogen.

Carbon prepares are cut utilizing compacted air (80% nitrogen and 20% oxygen) or unadulterated nitrogen. Nitrogen is utilized by the strategy for infusing water. A few frameworks use nitrogen as gas for building up plasma with oxygen which is infused into the plasma underneath the terminals. This course of action broadens the existence of the anodes since cathodes are not presented to the impact of oxygen. For certain cuttings of ferrous metals by a twofold stream framework, nitrogen is utilized for the plasma gas with carbon dioxide utilized for the safeguarding gas. For a superior nature of cuts, we utilize a combination of argon-hydrogen as the plasma gas and nitrogen as protection.

3.3.5 The direction of cutting

As we have already mentioned, most of the torches for plasma cutting swirls the gas for creation of plasma by its injection through the tangential holes or grooves in the head torch. One characteristic of gas swirl is more efficient arc energy transfer on one side of the slot. In the turbulence in the clockwise direction, e.g. the right side of the cut (looking in the direction of advancement) will be appropriate perpendicular, and the left side of the cut will be angled. Therefore, the advancing direction (cutting) must be performed so that the scrap metal is set to the left, as shown in Fig. 124. The components of the opposite swirl can be used if the perpendicular left side is required, e.g. when cutting opposite edges with two burners that are moving in the same direction. In manual operation, the operator makes the selection of the gas flow for creating plasma and current according to the list of recommended methods of operation. The operator sets the torch to the start place of cutting the workpiece and then establishes the arc. Then manually keeps moving the torch over the workpiece with the required cutting speed. Power and gas automatically turn off when you release the trigger on the gun (burner).

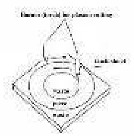


Figure 124.
The connection of the burner progression bearing to the

piece during the choppiness in the plasma gas

Note: Do not let the torch to touch the workpiece.
It should not be permitted the burner restricting spout to contact the workpiece. This would make harm the spout. Also, harm might happen in the event that the curve is crossed from the anode on the spout body and afterward on the piece (multiplying circular segment) rather than from the cathode to the piece. Designs of cutting burners normally limit issues of multiplying circular segment by the segregation or
by cutting indents in the nozzle.

3.3.6 Quality of cut

The elements that decide the nature of plasma cutting are the surface perfection, space width, parallelism of cut edges, slag which is shaped at the lower edge of the cut sides, cut symmetry and the upper edge sharpness. These variables are dictated by the kind of material to be cut, hardware development and its setting.

As a rule, excellent cuts are acquired with medium strength and low cutting paces. In any case, low cutting velocity compromises the monetary markers. Consequently, what comprises the necessary nature of the cut ought to be characterized before the application process.

Plasma cuts on sheets, thickness up to 75 mm can have a surface perfection basically the same as that acquired by oxy-gas cutting. Nearly there is no surface oxidation with the utilization of current programmed hardware that utilizations water infusion or water security. For thicker sheets, lower movement speed creates a more unpleasant surface finish.

Note: The widths of spaces for plasma slicing are 1.5 to twice more prominent than the width of the cut in oxy-gas fire cutting.

The width of plasma slice opening is 1.5 to twice higher than the oxy-gas slices on sheets thickness up to 50 mm. Eg. a regular opening width for treated steel of 25 mm thickness is roughly 4.8 mm contrasted with 3.2 mm space for the oxy-gas cutting. Opening width increments with the thickness of the sheet when utilizing plasma cutting, just as in different cycles of cutting. Plasma cut on 180 mm thick hardened steel made at 100 mm/min speed, has an opening width of 29 mm.

The plasma fly will in general eliminate additional metal from the upper piece of the space than from the base part. Along these lines, a run of the mill working cut plot for steel thickness of 25 mm is 4 to 6 ° from the completely equal edges of the cut. This incline is shaped on one side of the cut when the plasma-gas choppiness is utilized. Miter point on the two sides of the slice will in general increment with cutting speed.
Slag is a material that melts during the cutting and it is sticking (adhering) to the lower edge of the cut side. By the utilization of the today programmed gear we can deliver releases from slag or slag on aluminum and hardened steel up to a thickness of around 80 mm. In carbon steel, the decision of speed and electric power is more compelling on the slag which will in general shape on this material when you speed up. Adjusting of edges happens when overabundance power is utilized for cutting thick sheet, or when the protected distance of the light is excessively high. It can likewise happen when cutting with fast for material thickness under 6 mm.

3.3.7 Plasma cutters

The most straightforward plasma cutters are planned for manual cutting. Gas for acquiring plasma from these cutters is compacted air. The packed air should be dry and clean.

Different cutters require a specific tension and measure of compacted air, which addresses information for the attributes of the blower serving that shaper. The Fig. 125 presentations appearance one of the shaper models with packed air. Notwithstanding packed air, new age mechanical assembly for the arrangement of a plasma are utilizing argon, hydrogen, nitrogen, oxygen or their combinations. These gadgets are inverter type with extremely wide setting scope of boundaries so that as well as cutting they empower stamping. The presence of such item is displayed in Fig. 126.

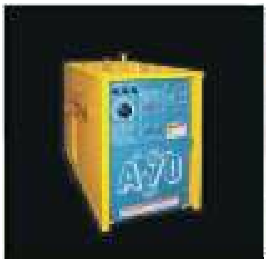


Figure 125.
Machine for cutting with compacted air
Figure 126.

Device for plasma cutting
Modern entryway plasma cutters are outfitted with CNC control systems.

Programming accuracy on these cutters is ± 0.01mm, and deviation incision is up to ± 0.1 mm. Software packages intended for the management of CNC cutters allow placing the cut line (path), the cut width compensation, the choice of cut form from the database of commonly used cut macros, automatic adjustment of the cutting parameters (speed, current, gas flow, etc.), based on the selected material to be cut and its thickness. The most common they are standardly equipped with plasma torch plus torch for flame cutting. Entering program is via the control unit equipped with LCD monitors, and data transfer via floppy disk units (rarely) compact discs, serial ports, USB or over the network.

Networking of CNC cutting machines with the offices for arranging and creation empowers persistent checking, control, and creation arranging. One of the projects for realistic programming of CNC machines for cutting administration is the program “ZEUS”, which is introduced as an administration support in certain cutters. In Figure 127, the audits of 50 macros are recorded, the structures can be:

- Rotated around the beginning stage for the ideal angle,
- Reflect (found in the mirror) over the X and Y axes,
- Scale (decline/increase)
- Swiveling slicing pivot pertinent to the workpiece,
- Dynamic pay of the cutting width, which gives the personality of CNC the executives, etc.

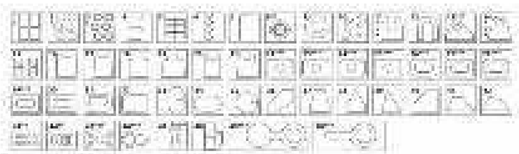


Fig. 127. Outline of the most usually utilized structures introduced on cutters

One of standard gear for cutters permits the import of different CAD files (DXF, IGS, PLT, ...) which implies that the machine can cut the ideal shape without the immediate planning of the program. The adornments on this cutters can include: programming for programming (ie. “ZEUS RX”), module for programmed cutting, positions laser pointer, air dryer and channel framework for extraction of gases created by cutting.


Fig. 128. The UI leading body of the control unit“BURNY Phantom ST “with 10.4” monitor

Notwithstanding the cutters, which are typically furnished with one plasma light, there are likewise cutters with the introduced burners for plasma and oxy-gas (fire cutting). These cutters have the choice of cutting greater thickness pieces, up to 300 mm. A thicker steel sheets are cut by the oxy-gas fire, while less thickness and non-ferrous materials are cut by plasma with altogether higher paces than the speed for the oxy-gas fire. In the Fig. 129 is given the presence of one of the cutters whose standard table aspects is up to 3000 x 6000 mm with the chance of augmentation of the longitudinal rail. Shaper in this model is outfitted with a control unit “Burny 10 LCD Plus” with 15” screen, control processor with working recurrence of 2GHz and the working framework is Windows XP. An illustration of workpiece projection showed on the screen is displayed in Figure 130. Subsequent to characterizing the size and shape, the place of components on the not really settled, or the ideal timetable that gives the most noteworthy abuse of the sheet.


Figure 129. Gantry

CNC shaper example

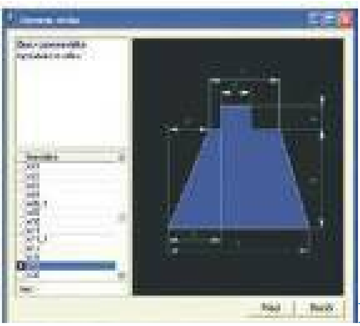


Figure 130. Illustration of the projected part showed on the screen of the cutters

Portal cutters are outfitted with gadgets for directing light tallness. The exhibitions of these gadgets are unique. The most straightforward is a contact gadget with pneumatic lifting/bringing down of the light with the sheet metal holder. The sheet metal holder guarantees a consistent distance between the burner and sheet metal during cutting and it is set physically. This gadget is planned for cutting sheet metal (up to 3 mm).

Figure 131a shows the gadget that permits manual aide control of the burner fire. Orders physically up/physically down move the light to the ideal position. Working reach (stroke) is 220 mm, and a sensor controls the deviation from the beginning signal.

Figure 131b shows the gadget fitted with capacitive sensor and control unit. Gadgets a) and b) can be introduced on any shaper with oxy-gas burner, the two gadgets have the capacity for controller, their directing accuracy is ± 0.3 mm.

Figure 131c shows the gadget utilized for the upward situating of oxy-gas or plasma light. This gadget gives two modes, to be specific: Arc sense MODE (for plasma burners) or Sens MODE (for oxy-gas burners). Attributes of Arc sense MODE are:

- Automatic stature acknowledgment for touching off the plasma arc,
- Automatic changing to change the tallness with the curve voltage,
- Adjustable time delay in the wake of cutting beginning, balancing out the

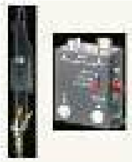
arc,

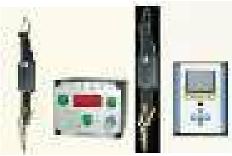
- Automatic acknowledgment of the space and the edge of the sheet,
- The customizable lifting of the light to the chose position in the wake of cutting ends.

Figure 131d shows a gadget intended for incredibly exact direction for plasma cutting or autogenous cutting with contactless or contact sensors. This gadget has every one of the highlights of the gadget c) with the extra chance of contact work for plasma cutting. Beginning situating is performed by contacting the spout and the workpiece, later bend start the tallness control is performed by the curve voltage.

Figure 132 shows the sensor contactless method of directing and contact situating with the direction of the light by the circular segment voltage.


a)


b)


c) d) Fig. 131. Gadgets for light (burner) tallness regulation

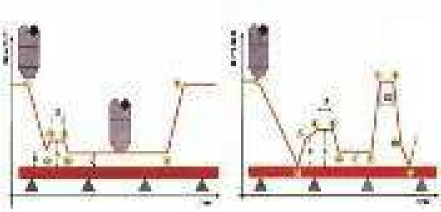

a) b)

Figure 132. Directing the burner in an upward direction by
a) a sensor (non-contact), b) contact.

3.4 Laser Cutting

Laser Cutting is additionally founded on a high-thickness force of this interaction, which causes the material that is sliced to rapidly arrive at the necessary temperature for laser cutting by dissolving, or dissipating temperature for laser cutting by sublimation. For cutting in modern conditions usually utilized is CO2 laser, Fig. 133. With the arrangement of focal points and the mirrors, the laser light emission is brought to the cutting head, where the focal point zeros in the pillar on the upper surface of the sheet. Laser radiates with CO2 laser for cutting, have a distance across of 0.1 to 0.01

mm, which is additionally the width of the cut. Because of the great thickness of force and speed, reducing with CO_2 laser is expense powerful, with superior grade of cutting surface and at least deformation.

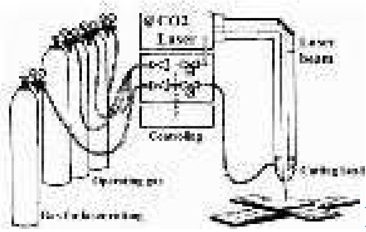


Figure 136. Schematic portrayal of the CO_2 laser cutting application