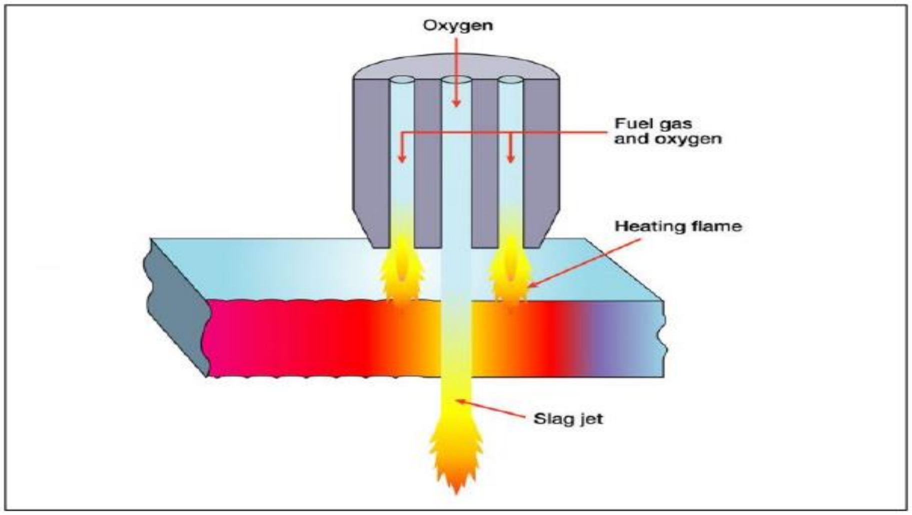
WELDING

Level-II

Based on March 2022, Curriculum Version 1



Module Title: - Performing Thermal Cutting

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List of figures

List of Tables

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Acronym

MAPP	methylacetylene-propadiene
CAC)	Carbon arc cutting
AAC)	Air carbon arc cutting
AOC	Oxygen arc cutting
SMAC	Shielded metal arc cutting
GMAC	Gas metal arc cutting
GTAC	Gas tungsten arc cutting
PAC	Plasma arc cutting

Introduction to the Module

In this Module we are going to describe how the same technique can be used to even cut the metal with the combination of oxygen and many other gases. Thermal cutting describes a group of cutting processes used to sever or remove or gouge metals by high-temperature exothermic reaction of oxygen with the base metal. With some oxidation resistant metals, the reaction can be aided by the use of a chemical flux or metal powder.

In this Module, we shall discuss several cutting processes. It shall include ox fuel gas cutting, Arc cutting processes etc. It will also include processes such as cutting through metal section several feet thick with oxygen lance cutting, flux cutting, flame drilling etc. in brief.

Unit One: Thermal Cutting Principles

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

- OHS Policies And Procedures
- Thermal Cutting Tools, Equipment and Consumables
- Assembled Thermal Accessories

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

- Familiarize OHS Policies And Procedures
- Select Thermal Cutting Tools, Equipment, materials and Consumables
- Select And Assemble Thermal Accessories
- Prepared Thermal Cutting Materials

1. Thermal Cutting Principles

1.1. Hazards and Assessment of Risks

A.The hazards

The hazards in gas welding and flame cutting can be broadly grouped into the following major categories:

- fire and explosion hazards;
- health hazards; and
- Other hazards specific to the operation, such as loss of stability to structures.

1. **Fire and explosion hazards**

Fire and explosion hazards in gas welding and flame cutting are mainly caused by problems with the gas supply system, the high temperature of the flame used or the hot slag produced in the process. These hazards include:

(a) Fires and explosions resulted from the release of flammable fuel gases or oxygen into the atmosphere from damaged gas hose or piping, or from leaks at joints, hose connections or fittings of the gas supply system, or as a result of valves of the gas supply line or blowpipe being left open inadvertently:

(b) Fires and explosions in the gas supply system caused by

(i) flashback from the blowpipe due to fuel gas supply lines not completely purged before lighting up, or back-feeding of fuel gas into the oxygen line or vice versa,

(ii) Decomposition or detonation of acetylene in the absence of oxygen or air due to flashback at the blowpipe or overheating of gas cylinder, or

(iii)high-pressure oxygen gas (without fuel gas) which promotes combustion of materials such as oil, grease, organic compounds, aluminum and its alloys, and elastomers used in valve seats and seals;

(c) Explosions from over-pressurization of the gas supply system;

(d) Fires arising from the flammable or combustible residue in the work piece; and

(e) Fires from the ignition of flammable or combustible materials in the vicinity by the flame of the blowpipe, hot surfaces of the work piece or hot slag from the process.

2. Health hazards

Health hazards of gas welding and flame cutting are mainly due to the radiation and toxic fumes or gases emitted during the process. The resultant health problems include:

a. Eye injuries, such as
   - Eye discomfort and burns from the intense light and heat emitted from the operation,
   - Heat cataract caused by radiation from molten metal, leading to inability to see things clearly, (iii) corneal ulcer and conjunctivitis from foreign particles e.g. slag and cutting sparks;

b. Skin irritation and reddening due to over exposure to radiation;

c. Illness due to inhalation of fumes or gases formed during the process, such as
   - Metal fume fever from freshly formed metal oxide fumes,
   - Illness from toxic fumes of metals such as lead, cadmium, beryllium,
   - Bronchial and pulmonary irritation from toxic gases such as oxides of nitrogen, fluorides;

d. burns from the blowpipe flame, hot slag or hot surfaces of the work piece;

e. heat-stroke from prolong operation with the flame, especially in confined space; and

f. Personal injuries arising from handling gas cylinders or large work pieces.

B. Risk assessment

1. Risk assessment in gas welding or flame cutting is an evaluation process to assess the likelihood of the hazards mentioned in Section 3.1 causing harm and the severity of that harm. This provides the necessary information for establishing appropriate safety measures, safe working procedures and emergency response procedures before commencing the operation. The scale and depth of the risk assessment depend on the working environment and the complexity of the welding or cutting operation.

The basic steps in risk assessment include:

(a) Identifying the hazards;

(b) Considering who may be affected and how;

(c) Evaluating the risks arising from the hazards, and considering whether existing safety measures are adequate or more should be done;

(d) Recording the findings unless it is easily explicable; and

(e) Reviewing the assessment from time to time and revising if necessary.

2. Risk assessment should be specific to the required task. Factors to be considered in assessing risks associated with gas welding or flame cutting operation include:

(a) The fuel gas and oxidant gas required and the gas supply system;

(b) The working environment, such as

(i) Ventilation of the workplace,

(ii) Working in specific environments, such as confined space, pressurized or oxygen-rich environment,

(iii) Working space restricting body movement,

(IV) Working nearby flammable or combustible materials, and

(v) The possibility of slag or sparks reaching or coming into contact with combustible materials;

(c) Particulars of the work, such as

(i) Duration and frequency of the welding or cutting operation,

(ii) Operation on work pieces with possible flammable or

(iii) Working at height, and (IV) size, shape and weight of the work pieces.

3. Risk assessment should be reviewed regularly and whenever there has been a significant change in the operation to which the assessment relates, such as changes in working environment or the particulars of the work.

C. Safety Measures

Overall strategy

The primary objective of adopting safety measures is to contain or reduce to as low as reasonably practicable the risks encountered in gas welding and flame cutting operations in protecting staff against injury or ill health. The primary consideration in selecting appropriate safety measures is to control hazards at source by control measures, whereas protective measures should be considered only as supplementary means in protecting staff against the hazards. Control measures, such as using appropriate ventilation and safety devices for the gas supply system, are effective means in controlling hazards at source. Protective measures using personal protective equipment provide protection to the workers concerned against the hazards during the welding or cutting process. However, the use of personal protective equipment should be a supplement to, and not in lieu of, effective control measures and the equipment should be selected appropriate to the required protection. Establishment, implementation and maintenance of safety measures should also include:

a. Proper design, construction and installation of plant and equipment, such as ventilation system, gas installation

b. Establishing safe work systems and procedures, including safety rules and safe working procedures;

c. Provision of appropriate information, instruction and training to the staff;

d. measures to ensure that equipment are properly used and maintained, safety rules are complied with and safe working procedures are followed by the staff, such as providing appropriate supervision to the workers; and

e. Regularly reviewing the effectiveness of the safety measures, safety rules and safe working procedures and revising the measures, rules and procedures whenever necessary.

A. Ventilation

Ventilation is a means by which contaminated air is removed from and fresh air is supplied to the workplace, and is an effective control measure to control fire and explosion hazards as well as the health hazards. The major functions of ventilation in the workplace include:

a. Removing gas from leakage, if any, so as to prevent accumulation of flammable/explosive mixtures in the atmosphere;

b. removing heat as well as hazardous fumes and gases such as metal and metal oxide fumes, oxides of nitrogen, fluorides arising from the welding or cutting operation; and

c. Supplying fresh air to meet the respiratory needs of persons inside the workplace.

For a workplace involving gas welding or flame cutting operations, the major types of ventilation are:

a. general dilution ventilation in which fresh air is introduced into the workplace by mechanical means and is mixed thoroughly with the contaminants in the air before removing the contaminants out of the workplace; and

b. Local exhaust ventilation in which air contaminants are captured and removed by forced air current through hood and duct near the point of emission and discharged to the atmosphere outside the workplace.

2. Personal protective equipment

In gas welding and flame cutting, the primary objective of using personal protective equipment is to provide protection to the workers against the risk of injury from hot objects and radiation as well as ill health from inhaling hazardous fumes, as a supplement to control measures.

Suitable training should be provided to workers for the proper use of personal protective equipment before they start the operation.

Eye protection

Eye protection equipment protects the eye from injuries by radiation and foreign objects such as slag and sparks arising from the welding or cutting operation.

a. Approved eye protectors such as goggles, visors, spectacles, face screens;
b. Approved shield such as hand shield; or
c. Approved fixed shield such as screen.

Skin and body protection

Skin and body protection includes protection to the face, hands, feet, body and personal clothing. The major objective is to protect workers against burns by the flame of the blowpipe, hot slag or work piece.

Respiratory protection

Respirators provide additional protection to workers from inhaling toxic fumes, and should be used in supplement to, but not in lieu of, the use of an efficient ventilation system. When welding or cutting is performed in a confined space,

3. **General Safe Practices**

A. Overview

Safety rules and safe working procedures, covering general safe practices in the industrial undertaking and safe practices in specialized operations, provide instructions to staff in ensuring safety and health at work. It may be necessary to display important rules and procedures in the form of notices and posters in the work area to arouse special attention.

The safe practices outlined below serve as a guide for establishing safety rules and safe working procedures on the general safety aspects regarding gas welding and flame cutting operations. The rules and procedures should be tailor-made according to the range of welding or cutting activities carried out in the industrial undertaking. The management of the industrial undertaking should ensure that the staff fully understand and comply with the rules and follow the procedures.

1.2. Thermal cutting tools, equipment and Consumables

1.2.1. Types of tools used to thermal cutting operation.

Tools are designed to make a job easier and enable you to work more efficiently. If they are not properly used and cared for, their advantages are lost to you. Regardless of the type of work to be done, you must have, choose, and use the correct tools in order to do your work quickly, accurately, and safely. Without the proper tools and the knowledge of how to use them, you waste time, reduce your efficiency, and may even injure yourself. This learning guide explains the specific purposes, correct use, and proper care of the more common tools you will use in thermal metal cutting work shop. Dear trainees these tools listed bellows are general tools used during working with thermal cutting and it selected in accordance with work requirements and specifications.

Basic tools used during working in thermal cutting shops are:-

Cutting equipment Portable flame cutting plants are identical to those used for oxyacetylene welding except they are fitted with a specially designed blowpipe and nozzle. An oxyacetylene cutting plant consists of the following components:

- Oxygen cylinder
- Acetylene cylinder
- Gas regulators
- Flashback arrestors
- Hoses
- Cutting blowpipe or torch
- Cutting nozzle
- Tip cleaners
- Cylinder trolley or cart (fitted with safety chain).

Gas cylinders

Oxygen cylinders and regulators are colored coded black and all fittings have right-hand threaded connections. Oxygen cylinders can be compressed up to a pressure of 17500 kPa. The pressure in the cylinder is directly related to the quantity of gas stored inside. Oxygen is odorless and is primarily used to support and accelerate combustion. Cylinders are available in G, E, and D and C sizes for different industrial applications.

As previously mentioned, oxygen by itself is not flammable or explosive; however it will support combustion and cause material to burn freely. When using and handling oxygen, never use it for:

- Operating pneumatic tools, spray painting or compressed air equipment
- Purging or blowing out pipelines, vessels or containers
- Freshening air or remove fumes in a confined space
- Cooling yourself or blowing dust from clothing.

Acetylene cylinders and regulators are colored coded claret, although they are sometimes referred to as maroon or crimson. Acetylene is a combustible fuel gas that gives off a distinctive garlic smell. All acetylene gas fittings have a left-hand threaded connection which are identified by a “notch” or grooved appearance on the outside of the fitting. Similar to oxygen, acetylene cylinders are available in G, E, D and C sizes to accommodate increased volumes of gas.

Cylinders are filled with a porous substance and acetone. Acetylene is dissolved in acetone to stabilize the gas allowing it to be stored safely up to I800 kPa. When combined with oxygen it will produce a flame temperature of approximately 3100°C which is higher than that achievable by LPG.

When handling and using acetylene it is important to:

- Keep cylinders in an upright position at all times
- Never transfer the gas from one cylinder to another
- Store cylinders in a cool, well ventilated location
- Never withdraw more than 1/5th or 20% of the cylinders contents over a 1 hour period. If this is likely to occur use gas supplied from a manifold or pack

LPG cylinders are color coded silver, grey or galvanized and have left-hand threaded connections. LPG is a highly flammable fuel gas that is given an artificial odour to indicate its presence and often used as an economic alternative to acetylene. Although LPG burns more efficiently than acetylene, the temperature of the flame, when combined with oxygen is lower (2800 - 2900°C) than that produced by acetylene and oxygen. For this reason LPG is limited to cutting and heating not welding applications.

Cylinder safety features

- Never attempt to interchange left-hand threaded pressure regulators between gases. Each regulator is designed for use with a specific gas, and to interchange them could be hazardous. Gas cylinder pressures and properties are different

- Acetylene should not be pressurized above 170 kPa as a free gas due to the possibility of an explosion
- Oxygen cylinders have bursting disc in its value assembly to avoid over pressurization of the cylinder

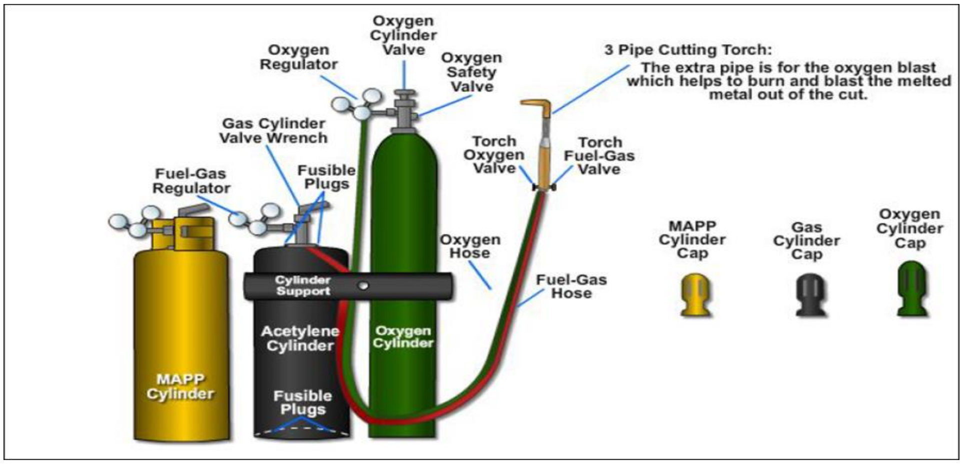


Fig 1.1 Oxy acetylene cutting assembled equipment

Numerous types of additional auxiliary equipment are available to improve the overall cutting operation; two of the most important are the spark igniter (commonly called a striker) and an apparatus wrench (commonly called a gang wrench) that fits all the connections on the cutting rig. The gang wrench has a raised opening in the handle that serves as an acetylene tank key (Figure 1-15).

Regulators

You must be able to reduce the high-pressure gas in a cylinder to a working pressure before you can use it. This pressure reduction is done by a regulator or reducing valve. The one basic job of all regulators is to take the high-pressure gas from the cylinder and reduce it to a level that can be safely used. Not only do they control the pressure but they also control the flow (volume of gas per hour).

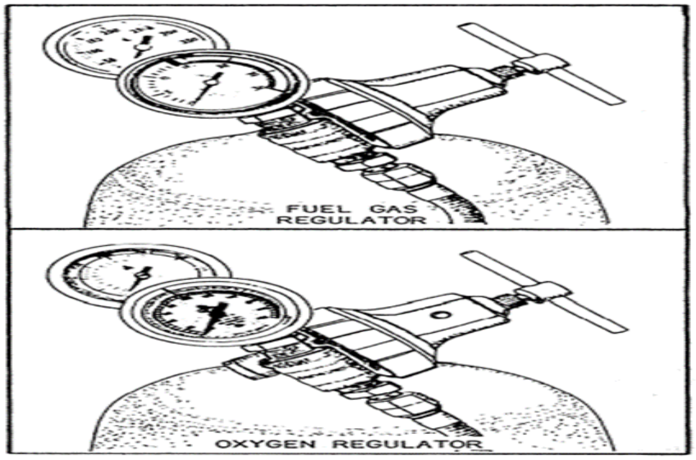


Figure 1.2.Single-stage regulators.

- **Hoses**

The hoses used to make the connections between the torch and the regulators must be strong, nonporous, light, and flexible enough to make torch movements easy. They must be made to withstand internal pressures that can reach as high as 100 psig. The rubber used in hose manufacture is specially treated to remove the sulfur that could cause spontaneous combustion. The most common type of cutting and welding hose is the twin or double hose that consists of the fuel hose and the oxygen hose joined together side by side. They are joined together by either a special rib (fig. 1-16, view A) Or by clamps (fig. 1-16, view B). Because they are joined together, the hoses are less likely to become tangled and are easier to move from place.

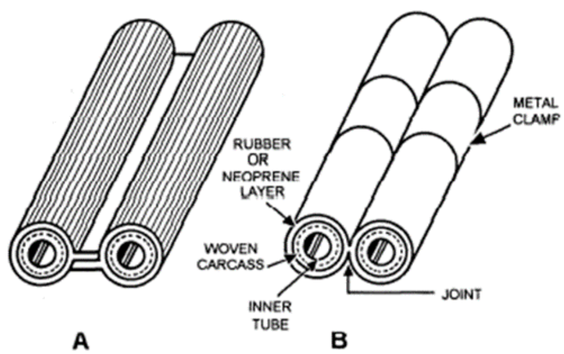


Figure 1.3. Types of twin welding hose.

- **Cutting Torches**

The equipment and accessories for oxy-gas cutting are the same as for oxygen welding except that you use a cutting torch or a cutting attachment instead of a welding torch. The main difference between the cutting torch and the welding torch is that the cutting torch has an additional tube for high-pressure cutting oxygen.

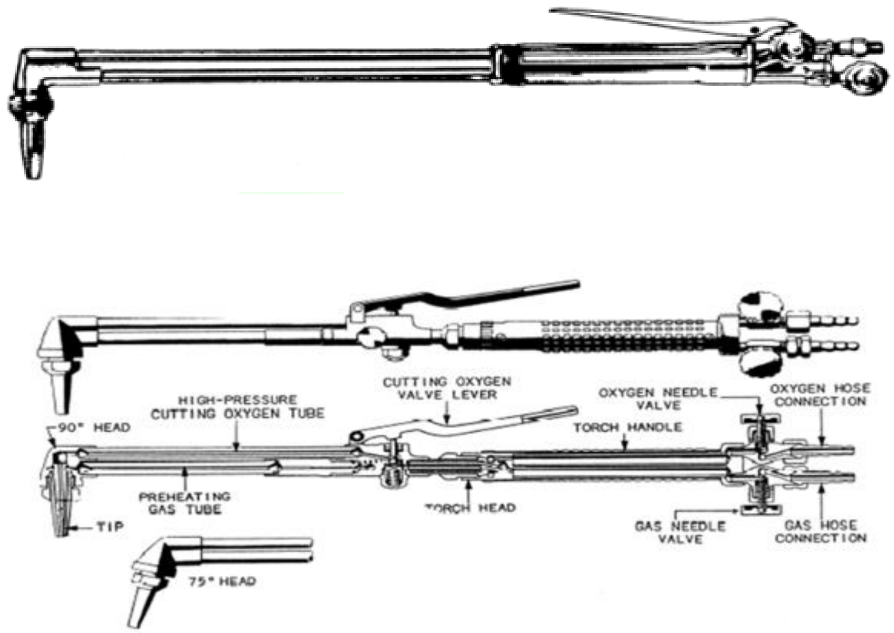
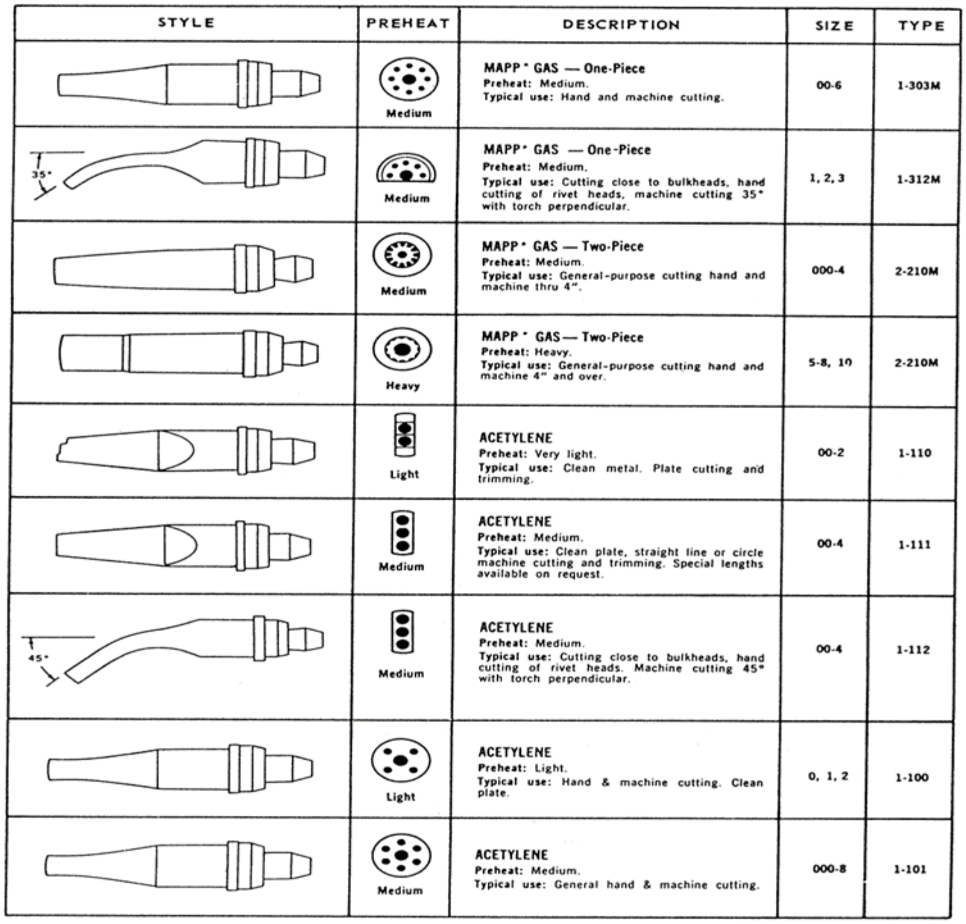


Figure 1.4.—Cutting attachment for combination torch.

- **Cutting Torch Tips**

As in welding, you must use the proper size cutting tip if quality work is to be done. The preheat flames must furnish just the right amount of heat, and the oxygen jet orifice must deliver the correct amount of oxygen at just the right pressure and velocity to produce a clean cut. All of this must be done with a minimum consumption of oxygen and fuel gases. Careless workers and workers not acquainted with the correct procedures waste both oxygen and fuel gas. This does not seem important when you are working in a shop, but if you are deployed,



STYLE	PREHEAT	DESCRIPTION	SIZE	TYPE
	Medium	**MAPP* GAS — One-Piece** Preheat: Medium. Typical use: Hand and machine cutting.	00-6	1-303M
35°	Medium	**MAPP* GAS — One-Piece** Preheat: Medium. Typical use: Cutting close to bulkheads, hand cutting of rivet heads, machine cutting 35° with torch perpendicular.	1, 2, 3	1-312M
	Medium	**MAPP* GAS — Two-Piece** Preheat: Medium. Typical use: General-purpose cutting hand and machine thru 4".	000-4	2-210M
	Heavy	**MAPP* GAS — Two-Piece** Preheat: Heavy. Typical use: General-purpose cutting hand and machine 4" and over.	5-8, 10	2-210M
	Light	**ACETYLENE** Preheat: Very light. Typical use: Clean metal. Plate cutting and trimming.	00-2	1-110
	Medium	**ACETYLENE** Preheat: Medium. Typical use: Clean plate, straight line or circle machine cutting and trimming. Special lengths available on request.	00-4	1-111
45°	Medium	**ACETYLENE** Preheat: Medium. Typical use: Cutting close to bulkheads, hand cutting of rivet heads. Machine cutting 45° with torch perpendicular.	00-4	1-112
	Light	**ACETYLENE** Preheat: Light. Typical use: Hand & machine cutting. Clean plate.	0, 1, 2	1-100
	Medium	**ACETYLENE** Preheat: Medium. Typical use: General hand & machine cutting.	000-8	1-101

Figure 1.5.Common cutting torch tips and their uses.

Some other common accessories include tip cleaner, tip drill set, hose connectors, extra striker and refill flints, extra cutting tip, hose repair kit, and a cylinder truck (Figure 1-16).

Figure 1-6. Typical oxygen accessories for cutting rig.

Oxy gas cutting equipment can be stationary or portable. A portable oxy gas outfit, such as the one shown in Figure 1-17, is particularly advantageous when you need to move the equipment from one shop cutting project to another. When working on a project field site, though, a cart with a larger set of wheels has a distinct advantage in moving over rough terrain, as in foundation work. In fact, building a cart with spooked metal wheels can be a shop-welding project with excellent field application later.

Equipment Setup

Setting up the oxygen equipment and preparing for cutting must be done carefully and systematically to avoid costly mistakes. To ensure your own safety, as well as the safety of your coworkers and equipment, make sure the following steps are taken before any attempt is made to light the torch:

Secure the cylinders so they cannot be accidently knocked over. A good way to do this is to either put them in a corner or next to a vertical column or then secure them with a piece of line. After securing the cylinders, remove the protective caps. Cylinders should never be secured to a structural member of a building that is a current conductor.

Standing to one side, crack each cylinder valve slightly and then immediately close the valve again. This blows any dirt or other foreign matter out of the cylinder valve nozzle. Do not bleed fuel gas into a confined area because it may ignite. Ensure the valves are closed and wipe the connections with a clean cloth.

- Connect the fuel-gas regulator to the fuel-gas cylinder and the oxygen regulator to the oxygen cylinder. Using a gang wrench, snug the connection nuts sufficiently to avoid leaks.
- Back off the regulator screws to prevent damage to the regulators and gauges and open the cylinder valves slowly. Open the fuel-gas valve only one-half turn and the oxygen valve all the way. Some fuel-gas cylinders have a hand wheel for opening the fuel-gas valve while others require the use of a gang wrench or T-handle wrench. Leave the wrench in place while the cylinder is in use so the fuel-gas bottle can be turned off quickly in an emergency. Read the high-pressure gauge to check the contents in each cylinder.
- Connect the RED hose to the fuel-gas regulator and the GREEN hose to the oxygen regulator. Notice the left-hand threads on the fuel-gas connection.
- To blow out the oxygen hose, turn the regulator screw in (clockwise) and adjust the pressure between 2 and 5 psig. After the hose has been purged, turn the screw back out again (counterclockwise) to shutoff the oxygen. Do the same for the fuel-gas hose, but do it ONLY in a well-ventilated place that is free from sparks, flames, or other possible sources of ignition.
- Connect the hoses to the torch. The RED (fuel-gas) hose is connected to the connection gland with the needle valve marked “FUEL.” The GREEN (oxygen) hose is connected to the connection gland with the needle valve marked “OXY.”
- With the torch valves closed, turn both regulator screws clockwise to test the hose connections for leaks. If none are found, turn the regulator screws counterclockwise and drain the hose by opening the torch valves.
- Select the correct cutting tip and install it in the cutting torch head. Tighten the assembly by hand, and then tighten with your gang wrench.
- Adjust the working pressures. The fuel-gas pressure is adjusted by opening the torch needle valve and turning the fuel-gas regulator screw clockwise. Adjust the regulator to the working pressure needed for the particular tip size, and then close the torch needle valve. To adjust MAPP gas, you should set the gauge pressure with the torch valves closed. To adjust the oxygen working pressure, you should open the oxygen torch needle valve and proceed in the same manner as in adjusting the fuel-gas pressure.

In lighting the torch and adjusting the flame, always follow the manufacturer’s directions for the particular model of torch being used. This is necessary because the procedure varies somewhat with different types of torches and, in some cases, even with different models made by the same manufacturer.

In general, the procedure used for lighting a torch is to first open the torch oxygen needle valve a small amount and the torch fuel-gas needle valve slightly more, depending upon the type of torch. The mixture of oxygen and fuel gas coming from the torch tip is then lighted by means of a spark igniter or stationary pilot flame.

1.2.3. Consumables Materials

Acetylene

Acetylene is a flammable fuel gas composed of carbon and hydrogen having the chemical formula

C_2H_2.Whenburned with oxygen, acetylene produces a hot flame, having a temperature between 5700°F and 6300°F. Acetylene is a colorless gas, having a disagreeable odor that is readily detected even when the gas is highly diluted with air. When a portable welding outfit, similar to the one shown in figure 4-3 is used, acetylene is obtained directly from the cylinder. In the case of stationary equipment, similar to the acetylene cylinder bank shown in figure 4-4, the acetylene can be piped to a number of individual cutting stations.

MAPP GAS

MAPP (methylacetylene-propadiene) is an all-purpose industrial fuel having the high-flame temperature of acetylene but has the handling characteristics of propane. Being a liquid, MAPP is sold by the pound, rather than by the cubic foot, as with acetylene. One cylinder containing 70 pounds of MAPP gas can accomplish the work of more than six and one-half 225-cubicfoot acetylene cylinders; therefore, 70 pounds of MAPP gas is equal to 1,500 cubic feet of acetylene.

OXYGEN

Oxygen is a colorless, tasteless, and odorless gas and is slightly heavier than air. It is nonflammable but supports combustion with other elements. In its free state, oxygen is one of the more common elements. The atmosphere is made up of about 21 parts of oxygen and 78 parts of nitrogen, the remainder being rare gases. Rusting of ferrous metals, discoloration of copper, and corrosion of aluminum are all due to the action of atmospheric oxygen. This action is known as oxidation.

1.3. Assemble Thermal cutting Accessories

Assembling Oxy-Fuel Cutting Equipment

- Identify step-by-step instructions to set up oxy-fuel cutting equipment
- Setting gas pressures for oxy-fuel cutting
- Identify the shutdown procedure for turning off oxy-fuel cutting equipment

1.3.1. Step by Step Instruction

1. Check equipment:
2. Purge the system:
3. Install the torch handle:
4. Connect the hoses:
5. Install the correct tip:
6. Adjust the pressure of the gas flow:
7. Turn on the gases:
8. Check the area:
9. Ignite the torch
10. Adjust the flame.

1.3.2. Setting Gas Pressure for Oxy-Fuel Cutting

Heating a component with an oxyacetylene torch uses the same nozzle set up as welding. The main difference is the increase in gas pressure. The pressure is increased to 10 psi for oxygen and 5 psi for acetylene. As you open the oxygen valve, you will see the color of the flame change. The pure acetylene flame is yellow, and it will change to blue as you add the oxygen. Continue to open the oxygen valve until you can observe a small, single light blue cone in the center of the torch flame. This is the “neutral” flame which is used for general heating. Approximate

PLATE THICKNESS		NOZZLE SIZE		GAS PRESSURES			
				Acetylene		Oxygen	
in.	mm	in.	mm	lbf/in^2	bar	lbf/in^2	bar
Acetylene							
1/8	3·2	1/32	0·75	2	0·14	15	1·05
1/4	6·4	1/32	0·75	2	0·14	25	1·8
1/2	12·5	3/64	1·0	2	0·14	30	2·1
1	25·4	1/16	1·5	2	0·14	35	2·5
2	51	1/16	1·5	2	0·14	45	3·2
3	76	1/16	1·5	2	0·14	50	3·5
4	100	5/64	2·0	2	0·14	60	4·2
6	150	5/64	2·0	2	0·14	75	5·3
Propane							
1/8	3·2	1/32	0·75	3	0·21	25	1·8
1/4	6·4	1/32	0·75	3	0·21	25	1·8
1/2	12·5	3/64	1·0	3	0·21	40	2·8
1	25·4	1/16	1·5	3	0·21	45	3·2
2	51	1/16	1·5	3	0·21	50	3·5
3	76	1/16	1·5	3	0·21	60	4·2
4	100	5/64	2·0	4	0·28	70	4·9
6	150	5/64	2·0	4	0·28	80	5·6
Natural gas							
1/8	3·2	1/32	0·75	Mains	—	25	1·8
1/4	6·4	1/32	0·75	Mains	—	25	1·8
1/2	12·5	3/64	1·0	Mains	—	30	2·1
1	25·4	1/16	1·5	Mains	—	45	3·2
2	51	1/16	1·5	Mains	—	55	3·9
3	76	5/64	2·0	Mains	—	60	4·2
4	100	5/64	2·0	Mains	—	65	4·6
6	150	3/32	2·5	Mains	—	70	4·9

Fig.1.7.Approximate Pressures for Hand Cutting Steel Plate.

Note: The above figures are given only as a guide since the actual requirements may vary according to the nature of the work. Some pressure regulators are fitted with gauges which are calibrated in kg/cm^2.1 kg/cm^2 is approximately equal to 1 bar.

1.3.3. Shut down Procedure

When you have finished with the cutting torch, you will need to shut down the equipment. Turn off the acetylene valve on the torch handle. This will extinguish the flame. Turn off the oxygen valve on the torch handle. Next, remove your safety goggles or mask and your welding gloves. Turn the main cylinder valve clockwise on the top of both gas cylinders. Now open the two valves on the torch handle to “bleed” the system. Turn both the oxygen and acetylene regulator handles counter-clockwise until they are loose. Close both valves on the torch handle. Put the handle and tips away, and return the gas cylinders and their hoses to their proper storage area.

1.4. Thermal Cutting Materials

The actual adjustment of the flame depends on the type of material to be cut. Shearing can be used straight line cut and thickness up to 40 mm. For thicker plates and contour, oxy fuel cutting is used. The difference in oxy acetylene gas cutting and acetylene welding is a torch tip which is used for preheating the plate as well as providing oxygen jet. The tip has a central hole for oxygen jet and surrounded holes for preheating flames. When high pressure oxygen jet with a pressure of order 300kPa is directed against a heated steel plate, the oxygen jet burn the metal and blows it away causing the kerf (cut).Larger the size of the orifice, wider is the kerf width and larger is the volume of the oxygen consumed.

Table.1.1.Tip sizes for cutting carbon steel

Plate thickness,mm	Oxygen orifice diameter,mm
Up to 3	0.65
3 to 6	0.90
6 to 250	1.25
25 to 5	1.60
50 to 100	2.25
100 to 200	3.00
200 to 300	4.25
300 to 400	5.00
400 to 500	6.00

Arc cutting

In arc cutting, the metal is simply melted by heat of arc and then blown away by force of arc or by any other gases such as air or shielding gases. Depending upon source of heat input, many arc cuttings are there.

- Carbon arc cutting(CAC)
- Air carbon arc cutting(AAC)
- Oxygen arc cutting(AOC)
- Shielded metal arc cutting(SMAC)
- Gas metal arc cutting(GMAC)
- Gas tungsten arc cutting (GTAC)
- Plasma arc cutting (PAC)

In all these processes, the equipment used is similar except the torch. The torch holds the electrode and supply high pressure gas where needed.

Carbon arc cutting

The process carries a carbon electrode to obtain the required arc. The metal that is cut is blown away by arc force and gravity.

Air carbon –arc cutting

Here the arc is obtained between copper coated graphite or carbon electrode and the work piece with molten metal being forced out by means of a compressed air at pressure of 550 to 690kPa.

Oxygen arc cutting

It carries a hollow tubular electrode to obtain the arc. Compressed oxygen is forced through a hollow portion so that metal is oxidized and blown in a similar manner as oxy fuel gas cutting (OFC).

Self-Check -1.

DIRECTIONS: Answer all the questions listed below.

Say true or false

Cutting of metals implies severing or removal of metal.

As material thickness increases, oxygen flow rates must usually be decreased.

Oxygen oxidizes the hot metal and also blows the molten reaction products from the joint.

II. Choose the best answer

1. One of the following is not thermal cutting process.

A. Oxy acetylene B. Plasma cutting C. cutting by power hack saw. D. None.

2. Personal protective equipment used to save our hands during cutting with thermal cutting and welding operation.

A. Welding/cutting glove B. Welding/cutting Goggle C. Face shield d. none

3. When you weld/cut or when you use angle grinders, sparks and other small pieces of metal fly everywhere, including under your helmet, how you Protect it from harm fullness?

A. Safety Glasses B. Safety shoes C. overcoat D. None

4. Typical oxygen cutting processes are ______ .

A. Chemical flux B. oxy-fuel gas C. metal powder cutting D. Ala.

5. When a piece is cut by an oxy-fuel cutting process, a narrow width of metal is removed; the width of the cut is called _______.

A. Chips B. a kerf C. Slag D. None

11. On materials up to 50 mm thick, kerf width can be maintained within________.

A. +0.4mm B. +0.2mm C. +0.5mm D. +0.6mm

Match Column "A" with Column "B"

"A"	"B"
1. Hazards in gas welding and flame cutting	A. Respiratory protection
2. Personal protective equipment	B. Fire and explosion
3. Used to make the connections between the torch and the regulators	C. Hoses
	D. Tips

Unit Two: Set up Thermal cutting outfit

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

- ✓ Manage and maintain work area
- ✓ Instructions, symbols, and specifications.
- ✓ Assemble and set up cutting equipment

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

- ✓ Manage and maintain work area
- ✓ Interpreting instructions, symbols, and specifications
- ✓ Assemble and set up thermal cutting equipment

2. Set up Thermal cutting outfit

2.1. Manage and maintain work area Man

2.1.1. Introduction

Welding, cutting, and brazing are potentially hazardous activities that pose a unique combination of fire, safety and health risks. The purpose of this written program is to reduce the risk of hazardous situations developing and to protect the health and safety of employees who are involved in welding, cutting, and other hot work operations.

General Requirements

All welding and oxyacetylene cutting outside a classroom setting shall be performed by trained persons. Prior to each welding or oxyacetylene cutting job, the condition of the equipment shall be inspected. Equipment in poor condition shall not be used until replaced or repaired. Examples of unacceptable conditions include cracked hoses or leads, taped hoses and leads, damaged sealing surfaces on fittings, regulators with inoperable gauges or other damage, missing backflow prevention devices and flash back arrestors, etc. The work area shall be evaluated for conditions that may make welding or oxyacetylene cutting unsafe. Welding screens shall be erected where other persons in the area may be exposed to arc flash, sparks or molten metal splashes.

Prior to each welding and oxyacetylene cutting job or other hot work:

- The condition of the equipment shall be inspected. Equipment in poor condition shall be reported to the employee's supervisor and not used until repaired or replaced.
- The work area shall be inspected for materials that are combustible or flammable. Combustible and flammable materials shall be moved to a safe distance from the work.
- Confirm that fire protection equipment, including fire extinguishers and sprinkler systems, are in working order.
- Confirm that exhaust systems, where needed, are operating.
- Obtain and complete the hot work permit and post at the job site until hot work is completed.
- Know when a fire watch is required and do not start work until the fire watch is present.
- Obtain and wear the necessary personal protective equipment.
- Welding screens shall be used where others in the area may be exposed to arc flash and/or cutting or welding splatter.

When hot work is completed:

- Return the hot work permit to the Building Lead when hot work is completed.
- Inspect the area after work is completed for weld splatter or sparks that may start a fire.
- Clean up welding or cutting residue and place in a clean metal container.
- Welding and oxyacetylene cutting equipment shall be properly stored.

No welding, cutting or other hot work shall be performed on used drums, barrels, tanks, bins, ductwork or other containers until they have been cleaned so that the following materials are no longer present:

- Flammable materials
- Combustible materials including dusts
- Greases
- Tars
- Acids
- Materials producing flammable or toxic vapors when subjected to heat.

2.1.2. Fire Prevention and Protection

Location of Work

Where feasible, welding, cutting, and other hot work shall be performed in designated welding or maintenance shops. Hot work performed outside designated areas will require a hot work permit.

Fire Watch

A fire watch is required where:

• Combustible materials cannot be moved a safe distance from the hot work area and cannot be covered with a fire-resistant covering.

• Hot work is in a building or area without automatic sprinkler protection.

The fire watch is responsible for:

• Ensuring that no sparks or hot embers land on combustible materials.

• Ensuring that fire protection equipment, such as fire extinguishers, is in the immediate work area and ready for use if needed. The minimum required fire protection is a 2A.20BC rated fire extinguisher.

• Extinguishing spot fires and communicating an alarm.

• Performing inspections of the work area after the hot work is completed. The final inspection of the work area shall take place no longer than 30 minutes past completion of the work.

• Being trained in the use of equipment including portable fire extinguisher and sounding the fire alarm.

2.1.3. Preparation of Work Area

Combustible/Flammable Materials

• If object to be welded or cut cannot be moved to a designated hot work area, all moveable fire hazards must be relocated at least 35 feet horizontally from hot work.

• Where relocation of combustible materials is impracticable, combustibles shall be protected with flame-proof covers.

• If fire hazards cannot be removed, then guards shall be used to confine heat, sparks, and slag and to protect the immoveable fire hazards.

• If the above requirements cannot be met, then welding, cutting or other hot work must be performed with a fire watch.

Openings

• Openings or cracks in walls, floors, ducts, or shafts within the hot work area shall be tightly covered to prevent the passage of sparks to adjacent combustible areas.

Floors

• Floors shall be swept clean of all combustible materials such as paper clippings, wood shavings, or textile fibers for a radius of 35 feet.

Pipes

• Cutting or welding on pipes or other metal in contact with combustible walls, partitions, ceilings or roofs shall not be undertaken if the work is close enough to cause ignition by conduction.

Sprinkler Detection

• Automatic sprinkler protection shall **not be** shut off while hot work is performed.

• Where hot work is performed close to automatic sprinklers, noncombustible barriers or damp cloth guards shall shield the individual sprinkler head and be removed when work is complete.

Compressed Gases

• Compressed gas cylinders such as oxygen, acetylene, and inert gases shall be stored and handled per 29 CFR.

Authority and Reference

- Occupational Safety and Health Administration (OSHA) 29 CFR 1910.252-1910.255
- international Fire Code (IFC) 2601-2609
- National Fire Protection Association (NFPA) 51B

2.2. Instructions, symbols, and specifications

2.2.1. Instructions and Precautions for Gas Cutting

A. SAFETY

1. Before handling or using any flame cutting equipment, understand and apply at all times the safe-practice instructions in this manual.

a. Be sure work areas are free of flammable and combustible or explosive materials.

b. Always wear protective personal equipment.

(1) A close-fitting hat with hair tucked in.

(2) Flame retardant clothing. *Shirt*- collar buttoned close around neck; pockets with flaps buttoned; full length sleeves, fastened at the wrist.

Trousers- must cover top of shoes no cuffs!

(3) High top work shoes.

(4) Approved eye protection.

(5) Leather work gloves.

B. Burning Equipment

1. Torches

a. A 2- or 3-hose machine torch 8 to 15 inches (203 to 381 mm) long is generally used on BUG-O machines.

b. 3-hose torches are recommended for heavy cutting on steel thicknesses up to 36 inches (914mm).

c. Torch valves, bodies and racks should be in good condition and have no gas leaks.

2. Hoses

a. Use ¼ inch (6.4mm) twin and single hose (red for gas and green for oxygen) with "B" size fittings. The (notched) fitting is for gas and the smooth fitting is for oxygen.

b. Fitting should be clamped tightly so there will be no gas or oxygen leakage.

c. Hoses with kinks, burned spots or small cuts are *very dangerous*, and will affect the quality of the cut.

d. If hose is damaged, should be spliced or scrapped. *NEVER USE TAPE TO STOP A LEAK.*

e. For a three-hose torch, the oxygen hose has a 3/8 (10mm) to ½" (13mm) inside diameter to allow a greater volume of oxygen flow for cutting.

f. The 50-foot (15.2m) standard length of hose should be used. Additional lengths of 25 feet (7.6m) can be added. It is important for the operator to know the exact total length of hose connected to the torch so the regulator gage can be set with the correct pressure. Increase oxygen pressure 5 pounds (3515 Kg/M^2) and gas pressure 1 pound (703 Kg/M^2) for each additional 25 feet (7.6m) of hose.

3. Regulators

a. Regulators are reducing valves used to reduce the high supply pressure to that which is desired. The gage on the regulator indicates the pressure at which gas is supplied to the torch.

b. The Regulators should be handled with care. Damaged regulators will give inaccurate pressure readings which will affect the quality of the cut. The needle should read 0 before pressure is applied.

c. Grease or oil should never be used on regulator fittings because they can cause burning or explosion of lines.

d. Gas and oxygen outlets should be blown out to remove grit or dust, before attaching to the regulator.

e. If needle on gage appears to be stuck when pressure is applied, tap lightly with your finger. If this does not cause the needle to move, the gage should be sent to the repair department.

4. TIPS

a. The proper care of a tip will allow many feet of burning before it wears out.

b. Tip cleaners should be used periodically to insure that holes are not plugged and that there are no burrs to deflect the gas.

c. The seat of the tip should be smooth to make a tight seal. If the seat is damaged, it will have a nick or nicks. This allows gas to escape and produces a flame around the top of the tip.

d. Tips should *never be thrown* in a tool box. They should be kept in their boxes or placed in special holding racks.

C. START UP PROCEDURE

1. HOOKING UP

a. Secure cylinders in upright position. Blow out gas and oxygen supply station outlets to remove any dust and grit particles.

b. Attach regulators to outlet. Finger tighten connections. Use a wrench to make snug. Be careful not to strip the threads.

c. Attach hoses to regulators. Finger tighten connections. Use a wrench to make snug. Be careful not to strip the threads.

d. Place BUG-O in approximate position to make cut.

e. Insert torch into holder on the BUG-O.

f. Attach hoses to the torch. Finger tighten connections. Use a wrench to make snug. Be careful not to strip the threads.

g. (1) Valves on torch should be closed.

(2) Turn valve on regulators counterclockwise until it moves freely so no pressure will register.

(3) Open acetylene cylinder valve ½ turn. Open oxygen cylinder valve all the way.

(4) Slowly open gas and oxygen valves on torch and turn wide open.

(5) Slowly turn in regulator valve until desired pressure is reached on gas and oxygen. (See torch manufacturer's tables for recommended oxygen and gas pressures.)

(6) Close valves on torch.

2. BURNING TIPS

a. Select tip (see torch manufacturer's table for recommended tip sizes).

b. Inspect tip.

c. Use tip cleaners to insure holes are clean and square on used tips.

3. BUG-O

a. Brush off dust/dirt form track grooves, work surfaces and magnet plates.

b. Place rail on work parallel to cut-line. Position torch over cut-line.

c. Adjust speed to approximate burning speed.

(1) Set indicator on 20, 30 or 40 on dial.

(2) Place torch tip ¼ inch (6.4mm) above plate and mark with soap stone. This is the starting point.

(3) Using the second hand on a watch, start the travel machine when the second hand is on 12.. Let the machine travel for one minute, then stop by throwing the switch.

(4) Using a soap stone, mark the spot where the tip stopped. Measure the distance between the two marks-*"This is inches (mm) per minute travel."*

(5) Repeat a different dial positions to establish correct speed settings.

(6) See tables for recommended travel speed settings.

4. LIGHTING THE TORCH AND SETTING THE PREHEAT FLAME

a. Adjust cutting goggles over eyes.

b. Put on gloves.

c. Open gas valve ¼ turn.

d. Open preheat oxygen valve 1/8 turn.

e. Put striker at tip end and light torch.

f. Adjust preheat flame to neutral by turning oxygen and gas valves one at a time and watching the blue flame cones for sharpness.

5. ADJUSTING THE PREHEAT FLAME FOR

MAKING A SQUARE EDGE CUT

a. A simple rule to follow when a square edge is desired is to have the preheat flame come out as a whisper rather than having a rush of gas and oxygen come out with such a force that the preheat flame has a shrill whistling sound. The whispering preheat flame has just enough heat to keep the leading edge and sides of the cut barely melting. Little sparkles will be present around the top surface of the hole which indicates that a correct preheat flame is used to give a square edge to the top of the cut. The whistling preheat flame has too much heat that keeps the leading edge and sides melting and will cause a rolled edge to the top of the cut.

b. Place tip half over the edge of plate.

c. Plate edge should start to get red.

1) If the plate edge does not start to melt (making fluid puddle), preheat flame is too cold.

2) If edge starts to melt too much (a fluid puddle the same diameter as the tip end), the preheat flame is too hot.

c) To adjust the too hot preheat flame (so that just enough heat is put into the plate to have a square edge on top of cut):

(1) Both the oxygen and gas valves must be slowly closed to reduce the preheat flame. First, close the oxygen valve slightly until the blue flame gets longer. Then close the gas valve until the blue flame shortens to the correct original length.

(2) Watch plate edge until fluid puddle is approximately ½ the size of the torch tip.

d. It is better to start with a cold preheat flame and slowly increase the oxygen and gas flow until a small molten fluid puddle appears on the starting edge of the plate.

1. START CUTTING

a. With acetylene, natural of propane gas the tip end should be placed about 1 to 3 times the length of the blue flame cones away from the plate surface (about 1/8 or 3/8" [3 or 10 mm] high). For MAPP gas the tip should be maintained from ¼ to 3/4" (6 to 19mm) from the plate.

b. The torch should be *square with the plate. Do not tilt torch.*

c. The top of the plate should be preheated for a distance of 1-1/2" to 2" (38 to 50mm) by moving the torch slowly back and forth over the area.

d. Bring torch to edge of plate so ½ of the preheat flame is touching the plate.

e. Hold at this position until a molten puddle starts to form (a little extra preheat oxygen sometimes is necessary to start this action and should be reduced after the cut is started).

f. Open cutting oxygen valve and start to cut.

g. Throw the travel machine switch to start travel along plate and immediately open the cutting oxygen valve to start cut.

h. If travel is not started immediately, the bottom 1/3 of the cut will pocket and gouge due to the expanding oxygen gas and the molten slag, the same as too slow a travel speed would make. The top of the cut should always lead the bottom of the cut even if it's only 1/16 (1.6mm) on an inch. This prevents the opening or kerf from being clogged with slag. It is better that the cut be made a little on the fast side, which would give a rippled wave appearance, rather than on the slow side which would require repairing or re-burning.

2.2.2. Symbols

For the purposes of International Standard, the following symbols for dimensional indications apply.

Table 2.1. Different types of thermal cutting symbols

Symbol	Term
a	work piece thickness
Δa	thickness reduction
A	assembly dimension
α	torch set angle
b	nozzle distance
B	programmed dimension of the cut part
β	cut angle
B_{z}	machining allowance
c	advance direction
d	top kerf width
e	cut thickness
f	length of cut
g	bottom kerf width
G_{o}	upper limit deviation
G_{u}	lower limit deviation
h	cutting direction
i	cut thickness
j	depth of root face
k	drag line
ln	evaluation length
lr	single sampling length
m	pitch of drag line
n	drag
o	groove depth
r	melting of top edge

Symbol	Term
$Rz5$	mean height of the profile
t_{G}	straightness tolerance
t_{P}	parallelism tolerance
t_{W}	perpendicularity tolerance
u	perpendicularity or angularity tolerance
Zt	profile element height

2.2.3. Specifications or Determination of the quality of cut surfaces

ISO 9013:2017(E)

Table 2.2. Coarse measuring instruments

Symbol	Precision measuring instruments	
	Error limits	Examples
u	0,02 mm	Guide device in the direction of the cut thickness and of the nominal angle with dial gauge Contact stylus point angle ≤90° Contact stylus point radius ≤0,1 mm
*Rz*5	0,002 mm	Precision measuring instrument, e.g. electric contact stylus instrument for continuous scanning in advance direction
n	0,05 mm	Measuring microscope with crosswires (crosshair) and cross-slide of sufficient adjustability
r	0,05 mm	Special device for scanning the profile of the cut upper edge by a dial gauge
Straightness	0,2 mm	Piano wire with max. 0,5 mm diameter, feeler gauge

Table 2.3. Coarse measuring instruments

Symbol	Coarse measuring instruments	
	Error limits	Examples
u	0,1 mm	Tri-square (workshop square with a degree of precision 1 or 2), for bevel cuts, bevel gauge or set square set to the nominal angle of bevel of cut or set angle, for this purpose depth gauge with sensing point, measuring wire, feeler gauge
*Rz*5	—	—
n	0,2 mm	Tri-square (workshop square) for bevel cuts, sliding square or set square, for this purpose calliper gauge with nonius or graduated ruler with nonius. Bevel gauge with conversion table from the drag angle to the drag length
r	0,1 mm	Convex gauge (radius gauge)
Straightness	0,2 mm	Piano wire with max. 0,5 mm diameter, feeler gauge

Please read the detail of the measurement conditions, measurement points and methods for determining and evaluating the characteristics of cut surfaces from the reference.

Self-Check -2.

DIRECTIONS: **Answer all the questions listed below.**

PART ONE:-**Say true or false**

1. All oxyacetylene cutting outside a classroom setting shall be performed by untrained persons.
2. Equipment in poor condition shall not be used until replaced or repaired.
3. Hot work performed outside designated areas will not require a hot work permit.
4. Performing inspections of the work area after the hot work is completed.
5. Automatic sprinkler protection shall not be shut off while hot work is performed.

PART TWO:-**Choose the best answer**

1. one of the following is material is no longer present welding, cutting or other hot work

   A. Acids B. Torch C. Flammable materials D. A and C

2. Before attaching to the regulator gas and oxygen outlets should be blown out to remove ______

   A. dust B. grit C. A and B D. none

PART TWO:-**Match Column "A" with Column "B"**

"A"	"B"
1. Thickness reduction	A. Tp
2. Single sampling length	B. r
3. Melting of top edge	C. Δa
	D. lr

Unit Three: Thermal cutting and gouging operation

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

- Cutting Process
- Equipment Start-Up and Adjustment Procedures
- Appropriate Material and Cutting Allowances

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

- Selected Appropriate Cutting Process
- Follow The Correct Start-Up And Adjustment Procedures Of Equipment
- Using Appropriate Material And Cutting Allowances

3. Thermal cutting and gouging operation

3.1. Thermal cutting Principles, applications and gouging operation

3.1.1. Cutting Principles and applications

Flame cutting, or oxy-fuel gas cutting as it is sometimes termed, is the most widely used thermal cutting process in metal fabrication industries for cutting steel sections to size and shape.

The operational principles of flame cutting were described in MEM05007C Perform manual heating and thermal cutting and stated that the process is reliant upon a chemical reaction taking place between heated iron and oxygen to form iron oxide; the iron oxide formed is then melted by the heat of the reaction and blown away by the oxygen jet. The flame cutting process uses a carefully controlled high-velocity oxygen stream to sever heated steel sections (cutting); or as in flame gouging, large volumes of oxygen at low velocity to remove defective welds or unwanted material. Cutting means the oxygen cutting jet is used on the part at 90° to produce a straight cut. Whereas for beveling, the cutting jet is used at an angle other than 90° to produce a chamfered or slanted face on the edge of the part. This is done to create a groove for a weld preparation or to remove a defective weld. Parts for a steel structure can be cut from plates, structural sections and pipes depending on the type of work required.

- Manual cutting is done where; a small number of parts are required; when the accuracy of the cut part does not have to meet restrictive tolerances or when flame cutting is performed on site
- Skilled operators can manually cut parts to a high level of accuracy, by freehand or guided cutting, if strict flame cutting skills are learned and attention is paid to detail
- when the accuracy of the cut point does not have to meet restrictive tolerance
- Where flame cutting is performed on site.

Examples, The oxy- fuel gas cutting process employs a torch with a tip (nozzle). The functions of a torch are to produce preheat flames by mixing the gas and the oxygen in the correct proportions and to supply a concentrated stream of high-purity oxygen to the reaction zone. The oxygen oxidizes the hot metal and also blows the molten reaction products from the joint. Features of cutting torches are shown in Figure 1.1.

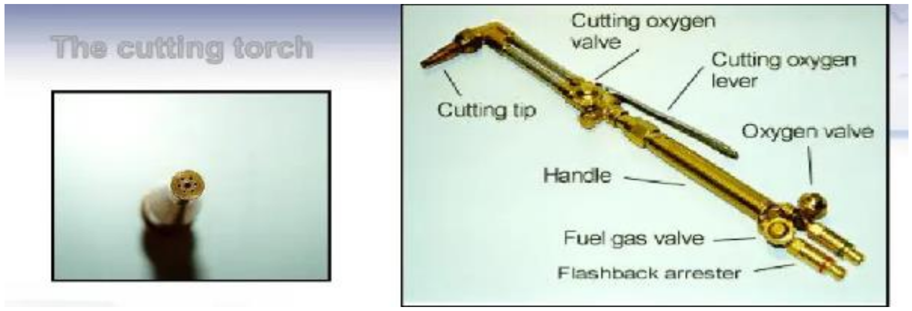


Figure 3.1. Features of cutting torches

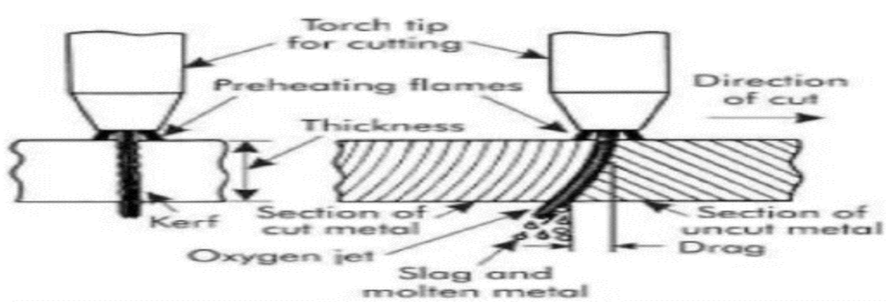


Fig.3.2. Principles of oxy-fuel cutting

3.1.2. Thermal Cutting Process:

Thermal cutting is one of the most important production processes in the metal producing and metalworking industries (e.g. in Structural engineering, machine fabrication, Energy equipment manufacturing shipbuilding and plant manufacturing etc.).

Thermal cutting primarily means the use of energy in various forms to cut virtually any shape from iron and nonferrous materials out of sheets or large slabs. These are the grades of the material which are usually referred as “Flats” in the metal processing industries. The other type of metals is available in angle, channel, beams, pipes, and rods etc. which are called as “Longs”. The series of article would cover primarily the cutting of the Flats & at a later date Longs.

3.1.3. Classification of thermal cutting processes

Thermal cutting processes are applied in different fields of mechanical engineering, shipbuilding and process technology for the production of components and for the preparation of welding edges. Thermal cutting can be categorized on the following requirements.

- Type material to be cut & its thickness
- The tolerance of the cut parts.
- Physics of the cutting process & its effects on the material

- Type of production
- Post cutting operations desired.
- The energy carrier.
- Application of the cut part.

The above criteria can be better understood with the following brief description.

1. Type of material to be cut & its thicknesses:

The selection of thermal cutting process would primarily be depending upon the type of material Ferrous, nonferrous & its thicknesses. We are representing the selection bubble diagram of Ferrous material so based on the thickness of the material the cutting process can be identified. The diagrams are having certain overlapping areas where 2 process can be fit in. There would be more criteria to use to further narrow down on the actual process.

2. The tolerance of the cut parts:

The tolerance of the various types of thermal cutting processes are each dedicated to the process basics, expressions, quality and dimensional tolerance. The quality characteristics, perpendicularity and angularity tolerances and the permissible calculated depth of roughness are set separately for the different cutting. One of the examples of tolerance is also mentioned in the above figures, similarly all other criteria would be covered in the subsequent articles.

3. Physics of the cutting process & its effects on the material:

We can distinctly separate the cutting by physics, which can be burning (chemical reaction) by oxidation, cutting by melting and vaporization cutting (also called as sublimation). The selection of the process would make an effect on the type of the material to be cut, its tolerances, chemical & physical reaction post cutting.

4. Type of production:

In various industries the type of production is categorized as cutting by manually operated tools, semi- mechanized cutting, fully mechanized cutting and automatic cutting. The volume of the production can also have a bearing on the selection of the process. The location of the cutting in the production like in- situ production, on site, open yard, enclosed area or normal factory site affects the process that can be used.

5. Post cutting operations desired:

The thermally cut parts which are parted from the mother plate are further taken for the post cut operations. In some of the operations there would be direct fitment, welding, grinding or bending, heat treatment etc. The process is greatly influenced by the post cutting operation desired.

6. The energy carrier:

The energy carrier is terminology used for the method in which the energy is used for metal removal it can be hot gases, electric gas discharge or by beam energy like light. They would be easily connected in the above sequence for gas, plasma & Laser. The usage of various energy carriers have direct implication on several physically & mechanical effects on the cut parts.

7. Application of the cut part:

The application of the cut parts as mentioned in the point no 5 can be further explained to understand that whether the part is subjected to mechanical stress, chemical reaction or fatigue etc. , this would directly determine the thermal cutting process to be used.

Basically from the above lists of the types of thermal cutting we will focuses our discussion on the energy carrier thermal cutting process, such as fuel gas, oxy fuel gas and air fuel gases.

3.2.3. The Oxy-Fuel Cutting Process

Because cutting is essentially an oxidizing process, little or no steel is melted. The kerf (the width of cut) should therefore be quite clean, and the top and bottom edges should be square. On examining melted oxides after cutting, it has been found that they contain up to 30 per cent un melted steel, which has been scoured from the sides of the cut by the high-pressure oxygen stream.

This scouring can be seen if the sides of the kerf are inspected, because drag lines will be faintly etched on the faces of the metal. For an incorrect cut, these drag lines will be more pronounced. The inspection and analysis of these drag lines can be used to improve cutting technique. (See illustration of drag lines below)

- Vertical lines – zero drag
- Drag measured against plate thickness, for example, 10% drag means a lag of 10% plate thickness.

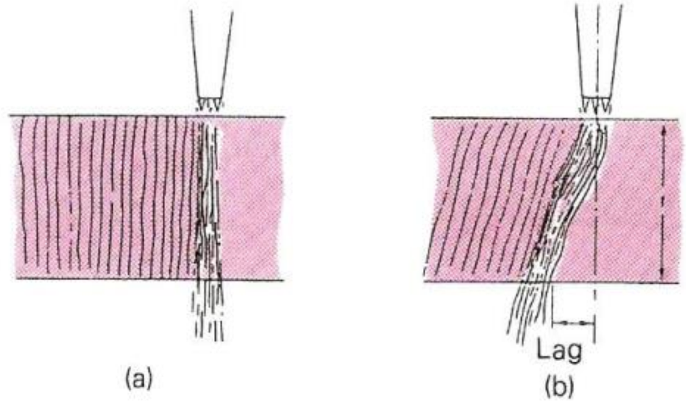


Fig.3.3. Drag Lines on Cut Plate

3.1.4. Identification of Issues with Flame Cut Edges

The table below identifies the difference between what is desirable and what is to be avoided with flame cut edge and how to achieve the desired result.

Table.3.1. different types of flame cut edge

	Good cut. • Sharp top and bottom edges. • Vertical drag lines. • No adhering dross. • Square face. Light, easily removed oxide scale.
	Cutting speed too fast. • Top edge not sharp. • Rounded bottom edge, which may not be completely severed. • Drag lines uneven, sloping backwards. • Irregular cut edge.
	Cutting speed too slow. • Rounded and melted top edge. • Bottom edge rough. Dross on bottom edge difficult to remove. • Lower part of cut face irregularly gouged. • Heavy scale on cut face.
	Nozzle too high. • Excessive melting of top edge. • Undercut at top of cut face.

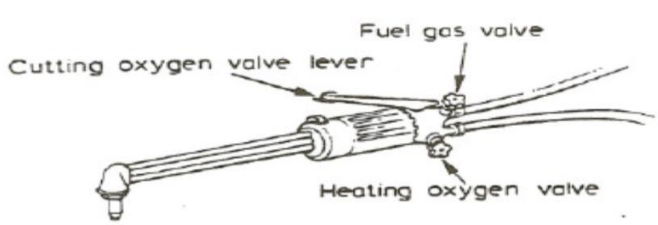
	Irregular cutting speed. • Wavy cut edge. Uneven drag lines.
	Preheating flame too high. • Rounded top edge. Irregular cut edge. Melted metal falling into kerf. • Excessive amount of dross adhering strongly to bottom edge.
	Preheating flame too low. • Bad gouging of lower part of cut face. • Cutting speed slow.

3.2. Equipment start-up and adjustment procedure

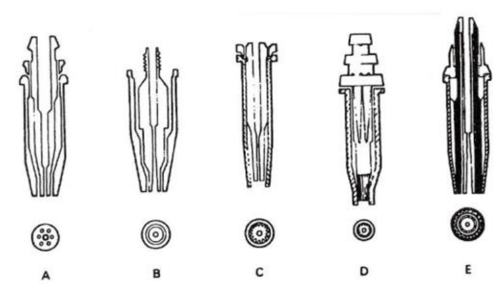
3.2.1. Identify the component parts of oxy-fuel cutting equipment

- Flame Cutting Equipment
- Cutting Torch
- Cutting Nozzles

Cutting Devices to Aid Cutting Movement



A.



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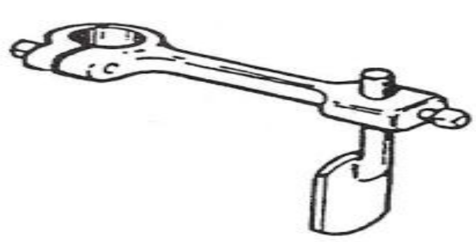

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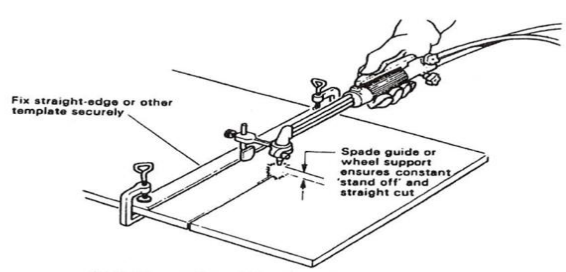

D.

Fig.3.4. component parts of oxy-fuel cutting equipment (A).Cutting Torch, (B). Typical Cutting Nozzle Design Feature, (C). Spade Guide and (D).Cutting with straight edge and single support.

Notes. A, B, C, D, E indicates

A. one-piece acetylene cutting nozzle – parallel bore, 3-9 pre-heat holes, no skirt.

B. two-piece acetylene cutting nozzle – venture bore, pre-heat annulus, no skirt.

C. two-piece natural gas nozzle-venture bore, pre-heat flutes, long skirt.

D. two-piece propane nozzle – parallel bore, pre-heat slots, long skirt.

E. two-piece propane nozzle – parallel bore, pre-heat flutes, long skirt, oxygen curtain.

Spade Guide - Is used to cut straight lines

3.2.2. Operation of Cutting Equipment Procedures

Setting up the oxyacetylene equipment and preparing for cutting must be done carefully and systematically to avoid costly mistakes. Refer below the Step-by-Step instructions before any attempt is made to light the torch:

Secure the cylinders so they cannot be accidently knocked over.

Standing to one side, crack each cylinder valve slightly and then immediately close the valve again.

Connect the fuel-gas regulator to the fuel-gas cylinder and the oxygen regulator to the oxygen cylinder. Using a gang wrench, snug the connection nuts sufficiently to avoid leaks.

Back off the regulator screws to prevent damage to the regulators and gauges and open the cylinder valves slowly. Open the fuel-gas valve only 1/2 turn and the oxygen valve all the way.

Connect the RED hose to the fuel-gas regulator and the GREEN hose to the oxygen regulator. Notice the left-hand threads on the fuel-gas connection.

To blow out the oxygen hose, turn the regulator screw in (clockwise) and adjust the pressure between 2 and 5 psig. After the hose has been purged, turn the screw back out again (counterclockwise) to shutoff the oxygen. Do the same for the fuel-gas hose, but do it ONLY in a well-ventilated place that is free from sparks, flames, or other possible sources of ignition.

Connect the hoses to the torch. The RED (fuel-gas) hose is connected to the connection gland with the needle valve marked “FUEL.” The GREEN (oxygen) hose is connected to the connection gland with the needle valve marked “OXY.”

With the torch valves closed, turn both regulator screws clockwise to test the hose connections for leaks. Select the correct cutting tip and install it in the cutting torch head. Tighten the assembly by hand, and then tighten with your gang wrench.

Adjust the working pressures. The fuel-gas pressure is adjusted by opening the torch needle valve and turning the fuel-gas regulator screw clockwise. Adjust the regulator to the working pressure needed for the particular tip size, and then close the torch needle valve. To adjust acetylene gas, you should set the gauge pressure with the torch valves closed. To adjust the oxygen working pressure, you should open the oxygen torch needle valve and proceed in the same manner as in adjusting the fuel-gas pressure.

In lighting the torch and adjusting the flame, always follow the manufacturer's directions for the particular model of torch being used. This is necessary because the procedure varies somewhat with different types of torches and, in some cases, even with different models made by the same manufacturer.

Hold the torch so that the cutting oxygen lever or trigger can be operated with one hand. Use the other hand to steady and maintain the position of the torch head to the work. Keep the flame at a 90 degree angle to work in the direction of travel. The inner cones of the preheating flames should be about 1/16 in. (1.6 mm) above the end of the line to be cut. Hold this position until the spot has been raised to a bright red heat, and then slowly open the cutting oxygen valve.

Cutting is initiated by heating the edge or leading face (as in cutting shapes such as round rod) of the steel to the ignition temperature (approximately bright red heat) using the pre-heat jets only, then using the separate cutting oxygen valve to release the oxygen from the central jet.

When cutting billets, round bars, or heavy sections, time and gas are saved if a burr is raised with a chisel at the point where the cut is to start. This small portion will heat quickly and cutting will start immediately.

CAUTION

NEVER use matches to light the torch; their length requires bringing the hand too close to the tip. Accumulated gas may envelop the hand and, upon igniting, result in a severe burn. Also, never light the torch from hot metal.

3.2.3. Cutting Mild-Carbon Steel

To cut mild-carbon steel with the oxyacetylene cutting torch, you should adjust the preheating flames to neutral. Hold the torch perpendicular to the work, with the inner cones of the preheating flames about 1/16 inches above the end of the line to be cut (refer figure below). Hold the torch in this position until the spot you are heating is a bright red. Open the cutting oxygen valve slowly but steadily by pressing down on the cutting valve lever.

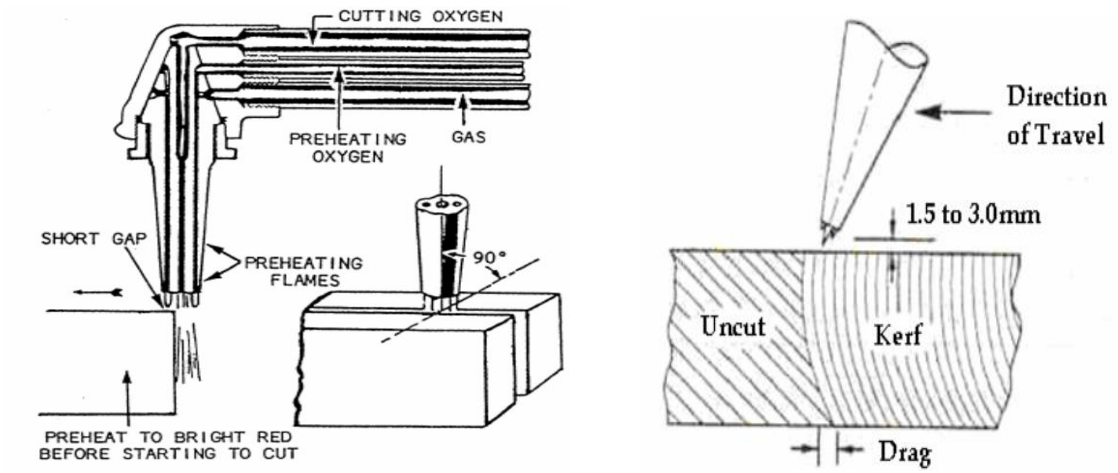

fig.3.5. position of Tip torch for start cutting

When the cut is started correctly, a shower of sparks will fall from the opposite side of the work, indicating that the flame has pierced the metal. Move the cutting torch forward along the line just fast enough for the flame to continue to penetrate the work completely. If you have made the cut properly, you will get a clean, narrow cut that looks almost like it was made by a saw. A good cut is characterized by very small or negligible drag. When the torch is moved too rapidly, the metal at the bottom does not get sufficient heat to get oxidized and cut and hence there is a large drag. When the torch is moved slowly, all the preheated metal is burnt away by the oxygen jet and a large amount of slag is generated.

*Kerf - The narrow slit formed in metal as cutting progresses. The ideal kerf is a narrow gap with a sharp edge on either side of the work piece; overheating the work piece and thus melting through it causes a rounded edge.

3.2.4. Cutting mild steel plate of normal thicknesses

General Cutting Techniques

The plate should be cleaned in the area where cutting will take place, and then positioned so as to be convenient for working (if possible). Invariably the flat position is the most convenient. The blowpipe should be held in a balanced position so that freedom of movement is possible. Hold the nozzle 3-5mm above before the plate surface and continue preheating until a bright red spot develops at the plate edge. The cutting oxygen valve should then be opened slowly until full flow is achieved. The blowpipe should then be moved at a steady speed along the line of the desired cut. In general, the speed will be correct when the slag sprays downwards immediately beneath the nozzle (i.e. zero drag). Care should be taken to ensure that complete penetration of the plate is achieved. The number of cutting interruptions should be kept to a minimum by ensuring that as long a cut as is possible is made. When it is necessary to interrupt a cut, a small hole adjacent to the kerf should be made in the unwanted plate and the cutting oxygen turned off before the blowpipe is withdrawn. To recommence the cutting, start in the area of the hole and as cutting commences continue as before.

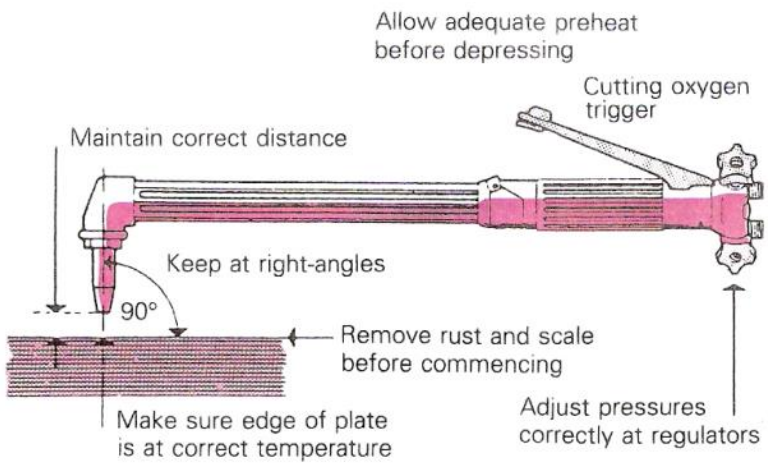

Fig.3.6. Basic Cutting Techniques

3.2.5. Cutting Techniques for Thick Material

Because of the heavy gas consumption when cutting thick material, ensure that there is "an adequate supply of fuel gas and use a battery of oxygen cylinders coupled together or pipeline supplies. On very thick material, heat metal to bright red heat, operate the cutting lever, wait until the cutting reaction is seen to be right through the metal thickness to the bottom edge, and then draw the blowpipe along.

3.2.6. Cutting Thin Steel

Though the gas cutting is more useful with thick plates, thin sheets (1/8 inch or less) can also be cut by this process taking special precautions. Tip size chosen should be as small as possible. If small tips are not available, then the tip is inclined at an angle of 15 to 20 degrees and point the tip in the direction the torch is traveling. By tilting the tip, you give the preheating flames a chance to heat the metal ahead of the oxygen jet, as shown in figure below. If you hold the tip perpendicular to the surface, you decrease the amount of preheated metal and the adjacent metal could cool the cut enough to prevent smooth cutting action.

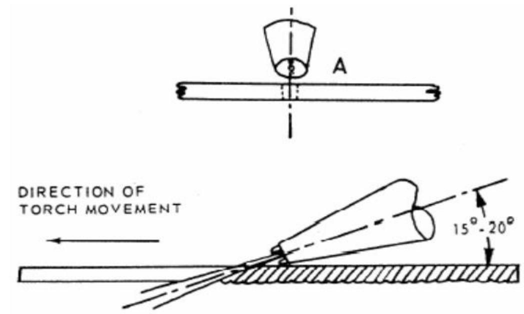

Fig.3.7. Torch position for cutting thin sheets

3.2.7. Cutting Techniques for Painted or Galvanized Material

Clean the surface before starting to cut. It is often an advantage to incline the tip of the nozzle a little to help to undercut paint or scale. Unless ventilation is very good fume extraction should be installed at the point of cutting. In some cases it may be necessary to use a respirator as well.

3.2.8. Cutting Techniques for Stack Cutting

Multiple components of the same shape can be cut at one time by stacking and clamping plates tightly together. The shape is marked on the top plate and the profile is cut in the normal way.

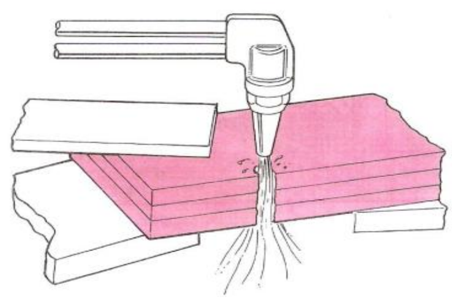

Fig.3.8. Stack Cutting

3.3. Appropriate cutting allowances

The oxy-fuel process is the most widely applied industrial thermal cutting process because it can cut thicknesses from 0.5mm to 250mm, the equipment is low cost and can be used manually or mechanized. There are several fuel gas and nozzle design options that can significantly enhance performance in terms of cut quality and cutting speed.

Fig.3.9. Mechanized oxyacetylene cutting system

3.3.1. Common gauge settings for cutting

- 1/4” material - Oxygen: 30-35psi; Acetylene: 3-9 psi
- 1/2” material - Oxygen: 55-85psi; Acetylene: 6-12 psi
- 1” material - Oxygen: 110-160psi; Acetylene: 7-15 psi

3.3.2. General Cutting Information

There is a wide variety of cutting tip styles and sizes available to suit various types of work. The thickness of the material to be cut generally governs the selection of the tip. The cutting oxygen pressure, cutting speed, and preheating intensity should be controlled to produce narrow, parallel sided kerfs. Cuts that are improperly made will produce ragged, irregular edges with adhering slag at the bottom of the plates. Table below identifies cutting tip numbers, gas pressures, and hand-cutting speeds used for cutting mild steel up to 12 in. (304.8 mm) thick.

Table3.2. Oxyacetylene Cutting Information

Plate thickness (inches)	Cutting tip (size number)	Oxygen (psi)	Acetylene (psi)	Hand cutting speed (inches per minute)
¼	0	30	3	16 to 18
3/8	1	30	3	14.5 to 16.5
½	1	40	3	12 to 14.5
¾	2	40	3	12 to 14.5
1	2	50	3	8.5 to 11.5
1½	3	45	3	6 to 7.5
2	4	50	4	5.5 to 7
3	5	45	4	5 to 6.5
4	5	60	5	4 to 5
5	6	50	5	3.5 to 4.5
6	6	55	6	3 to 4
8	7	60	6	2.5 to 3.5
10	7	70	6	2 to 3
12	8	70	6	1.5 to 2

Note: Check the torch manufactures data for tip identification number and optimum pressure settings

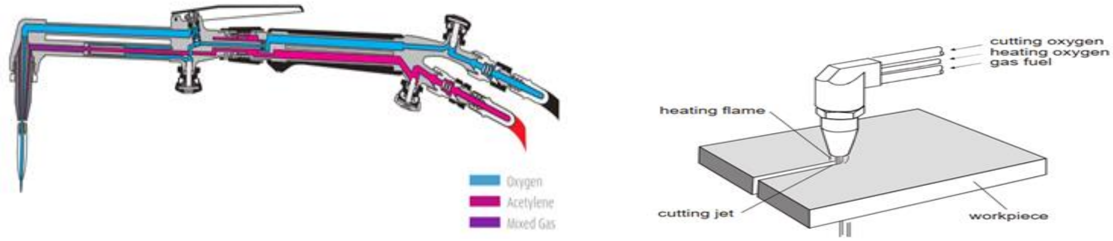

Fig.3.10. Oxygen cutting

3.3.3. Safety Precautions in Cutting Operations

- Never use a cutting torch where sparks will be a hazard;
- Sweep floors clean and wet them before cutting;
- Provide a bucket of water or sand to catch dripping slag;
- Use fire-resistant guards, partitions or screens if necessary;
- Take extra precautions while working in greasy, dirty, or gaseous atmosphere
- Keep combustible materials at least 35 ft. away from cutting operations;
- Never cut near ventilators;
- Never use oxygen to dust off clothing or work pieces or as a substitute for compressed air;
- Locate the nearest fire extinguisher before performing any welding or cutting operation;
- Purge oxygen and acetylene hoses before lighting torch;
- Never move cylinders without protective caps in place;
- Wear personal protective equipment.
- Wear welding gloves, helmet, leather apron, welding chaps, leather shoes, welding goggles, and other personal protective equipment
- Make sure the welding goggles or face shield have at least a No. 4 filter lens;
- Do not wear clothing made of synthetic fibers while welding;
- Fasten cylinders securely. Do not handle cylinders roughly. Chain cylinders in an upright position to a wall or cart. When regulators are not on cylinders, keep safety caps in place. Caps will prevent damage to cylinder valves;
- Never use oil on welding equipment. Oil and grease may ignite spontaneously, when in contact with oxygen;
- Open cylinder valves correctly. Open the valve on the acetylene cylinder no more than three-fourths of a turn (maximum one turn) so it can be closed quickly in case of

emergency. Open the valve on the oxygen tank fully. While welding or cutting, leave the valve wrench in position;

- Keep the tip pointed away from your body. Do not saturate your clothing with oxygen or acetylene. Before and while lighting the flame, keep the tip pointed away from your body;
- Light the flame with an approved lighter. Using matches to light the torch brings fingers too close to the tip;
- Set the operating pressure carefully. Never use acetylene at a pressure over 15 psi;
- Do not leave the work area until the cylinder valves are closed. Be sure the cylinder valves are closed and pressure is relieved from the hoses before you leave the work area;
- Do not cut on containers that have held flammable materials;
- Store oxygen cylinders away from acetylene cylinders. A non-combustible wall at least 5 feet high should be used to separate cylinders.

3.4. Defects and its Causes of defects action

3.4.1. Imperfections on flame-cut edge

Rounded cut edges-

- Travel too slow,
- Nozzle-to-plate distance too large,
- Nozzle-to-plate distance too small,
- Nozzles too large for thickness to cut,
- Flame to strong and Excess oxygen flame

Beaded cut edges-

- Nozzle-to-plate distance too small,
- Flame to strong & Surface scaled or rusty

Edge overhand-

- Nozzle-to-plate distance too small,
- Flame to strong

Melted-down top edge with firmly adhering slag-

- Nozzle-to-plate distance too large,
- Flame to strong & Excessive cutting oxygen pressure.

3.4.2. Imperfections on flame-out faces. Perpendicularity and angularity tolerance

Grooved cut face below top edge-

- Nozzle-to-plate distance too large,
- Dirty nozzles,
- Excessive cutting oxygen pressure & Cutting oxygen jet disturbed

Narrowing kerf (convergent)

- Excessive blowpipe travel
- Nozzle-to-plate distance too large
- Dirty nozzles

Widening kerf (divergent)

- Excessive blowpipe travel
- Excessive cutting oxygen pressure
- Excessive cutting oxygen flow rate

Concave cut face

- Excessive blowpipe travel
- Nozzle-to-plate distance too large
- Nozzles too small for thickness to cut

Wavy cut face profile

- Excessive blowpipe travel
- Dirty nozzles
- Nozzles damaged or worn

Angular deflection

- Position of b. not rectangular with respect to work surfac
- Cutting oxygen jet deflected

Rounded bottom edge

- Dirty nozzles
- Nozzles damaged or worn
- Cutting oxygen jet disturbed

Grooved face above bottom edge

- Excessive blowpipe travel
- Dirty nozzles

- Nozzles damaged or worn

3.4.3. Imperfections on flame-cut faces. Deviations from drag line pattern.

Excessive backward inclination of drag lines

- Forward inclination of drag
- Excessive forward inclination of drag at bottom
- Local drag line deflection
- Excessive depth of drag lines
- Irregular depth of drag lines

3.4.4. Imperfections on flame-cut faces: Lost cut

Bottom section not severed

- Excessive blowpipe travel

Interrupted cutting action.

- Nozzles too small for thickness to c
- Dirty nozzles
- Nozzles damaged or worn

3.4.5. Gouging

Isolated

- Backfiring
- Cutting oxygen jet deflected

Accumulated-

- Excessive blowpipe travel,
- Nozzle-to-plate distance too small,

Gouging especially in bottom part-

- Travel too slow,
- Dirty nozzles ,
- Flame too weak

3.4.6. Adhering slag

Slag adhering to bottom edge-

- Excessive blowpipe travel,
- Travel too slow,
- Nozzles too small for thickness to cut,

- Excess fuel gas flame,

Crust of slag-

- Alloying elements content too high

3.4.7. Cracks

In the cut face-

- due to Carbon content too high,
- Alloying elements content too high,
- Steel susceptible to hot cracking,
- Work piece insufficiently preheated,
- Rapid cooling of work piece & Material strain hardened

Below the cut surface-

- Carbon content too high,
- Alloying elements content too high,
- Steel susceptible to hot cracking,
- Work piece insufficiently preheated,
- Rapid cooling of work piece & Material strain hardened

3.4.8. General common defects for all are:-

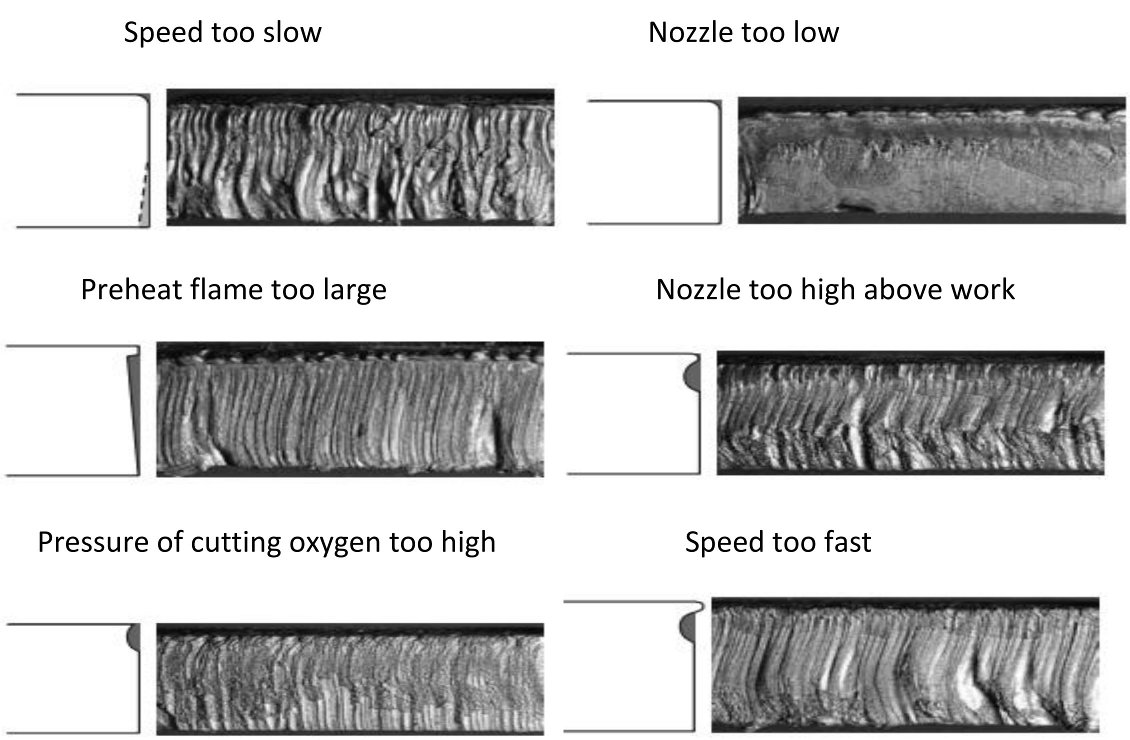

Fig.3.11. defect gas cutting

Correct Conditions

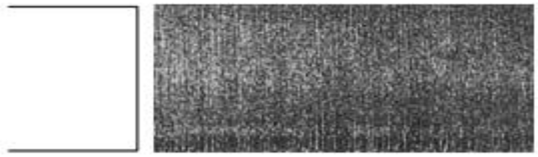

Fig.3.12. correct condition of gas cutting

3.5. Heat, cut or gouged thermal materials

3.5.1. Preheating Fuels

Preheating fuels perform a particular function. Understanding of the function will help in proper selection of the fuel. In this section preheating fuel functions and their individual characteristics are discussed.

Functions of the preheat flames in the cutting operation are the following:

- Raise the temperature of the steel to the ignition point,
- Add heat energy to the work to maintain the cutting reaction,
- Provide a protective shield between the cutting oxygen stream and the atmosphere, and
- Dislodge from the upper surface of the steel any rust, scale, paint, or other foreign substance that would stop or retard the normal forward progress of the cutting action.

A preheat intensity that raises the steel to the ignition temperature rapidly will usually be adequate to maintain cutting action at high travel speeds. However, the quality of the cut will not be the best. High quality cutting can be carried out at considerably lower preheat intensities than those normally required for rapid heating. On most larger cutting machines, dual range gas controls are provided that limit high-intensity preheating to the starting operation. Then the preheat flames are reduced to lower intensity during the cutting operation, to save fuel and oxygen and provide a better-cut surface. A number of commercially available fuel gases are used with oxygen to provide the preheating flames. Fuel gases are generally selected because of availability and cost. Combustion intensity or specific flame output for various fuel gases is another important consideration in fuel gas selection.

3.5.2. Fuel Selection Criterion

The following are some general factors for consideration when selecting a preheat fuel:

- Time required for preheating when starting cuts on square edges and rounded corners, and also when piercing holes for cut starts,
- Effect on cutting speeds for straight line, shape, and bevel cutting,
- Effect of the above factors on work output,
- Cost and availability of the fuel in cylinder, bulk, and pipeline volumes,
- Cost of the preheat oxygen required to burn the fuel gas efficiently,
- Ability to use the fuel efficiently for other operations, such as welding, heating, and brazing, if required, and
- Safety in transporting and handling the fuel gas containers. For best performance and safety, the torches and tips should be designed for the particular fuel selected.

3.5.3. cutting/going process

- ➢ arc cutting processes such as carbon arc cutting, shielded metal arc cutting (smac)
- ➢ oxygen arc cutting
- ➢ metal powder cutting
- ➢ flux cutting
- ➢ oxygen lance cutting
- ➢ flame gouging

Notes:-Please refer and read the detail of the above cutting or going process from the reference books.

3.6. Safety in Operation & Use

Acetylene is unstable at pressures above 15 PSI; NEVER release acetylene, or any other fuel gas in confined spaces, where it might cause a fire or explosion; DO NOT open an acetylene cylinder valve more than one turn. This permits adequate flow of acetylene from the cylinder and allows for quick closing of the valve in an emergency situation; to open and close acetylene cylinder valves not provided with hand-wheels, always use the special wrench or key provided by the supplier. Leave the wrench or key in position, ready for immediate use should it be necessary to close the valve promptly. (When several cylinders are manifold together, a wrench on every cylinder is not required.) More than 1/10 the capacity of the cylinder should not be used per hour. This causes the acetylene to rapidly come out of solution, like carbon dioxide bubbles violently fizzing from a fizzy soft drink that has just been shaken; Oxygen cylinder contains pressures over 2000 PSI and must be handled carefully; Pure oxygen will accelerate combustion to the point that it can cause an explosion; Do not use oxygen to dust off clothing or the work area; Use the correct size wrench when tightening or loosening fittings. They are made of brass and can be damaged easily; when not in use, cylinder must have a protective cap installed; NEVER use a cylinder that is leaking. If leakage around the cylinder valve stem is detected after the valve has been opened (one and one-half turns for an acetylene cylinder, as far as possible for an oxygen cylinder) close the valve tight and return it to your supplier after tagging the cylinder to tell him that the valve is unserviceable; Stand to the side of the equipment when opening the cylinder valves, and open them slowly. This will limit the risk of injury due to exploding regulators; Only use a friction lighter to light your torch; Hot metal left out should be marked “HOT” so the others will not be burned by it; Use pliers or tongs to grab hot metal; Do not weld or cut on a closed container;

Inspect the hoses frequently and when necessary replace them; ALWAYS keep oxygen and acetylene cylinders vertical upright at all times. Do not store them in the horizontal position; if an acetylene cylinder is used in the horizontal position, solvent may be lost and flame quality may be affected; Store oxygen cylinders separately from fuel gas cylinders. Unless a fire-resistant noncombustible partition, at least 5 feet high, is used to separate the two types of cylinders or a minimum 20-foot separation should be maintained; Oil, grease, coal dust, and similar organic materials are easily ignited and burn violently in the presence of high oxygen concentrations. Never allow such materials to come in contact with oxygen or oxy-acetylene equipment, including hose. Oxy-acetylene apparatus does not require lubrication; DO NOT use pipe-fitting compounds or thread lubricants for making connections. Connections for oxy-acetylene and oxygen-fuel gas equipment are designed so that they can be made up tight without the need for lubricants or sealants. Of special importance is the need to keep all materials containing oil and grease away from equipment that uses oxygen.

Lighting Torch

Purge lines daily before lighting to remove air and other contaminants from hoses. Open each torch valve in turn long enough for the pure gas to purge out any gas mixtures. Shut one valve before opening the other. Do NOT purge in a confined space, in the presence of flame or other source of ignition, or toward people; Point tip away from yourself and others when lighting and using torch; Use spark lighter or pilot light to light torch. Do NOT use matches or cigarette lighter, hand burns may result; light as follows: Open fuel valve and ignite gases flowing from tip. Adjust fuel valve for full flow without blowing off. Adjust oxygen valve to desired flame.

Extinguishing Flame:

Close oxygen and (without delay) fuel torch valves tightly; check for gas leak from tip or valves; Leave torch in safe position to prevent accidental dislodging that may open valves or cause damage; Leaving Equipment unattended (lunch or overnight): Extinguish flame by closing torch valves; Close cylinder valves.

Leaving equipment unattended (over weekend or longer): Extinguish flame by closing torch valves and close cylinder valve; Drain gas from regulators by opening torch valves, venting gases in safe direction, then closing valves one at a time. If in public area, disconnect and store equipment to prevent unauthorized or accidental use, which may create a hazard; Purge lines before lighting or reuse.

Process fundamentals

The cutting process is illustrated in Fig. 1. Basically, a mixture of oxygen and the fuel gas is used to preheat the metal to its 'ignition' temperature which, for steel, is 700°C - 900°C (bright red heat) but well below its melting point. A jet of pure oxygen is then directed into the preheated area instigating a vigorous exothermic chemical reaction between the oxygen and the metal to form iron oxide or slag. The oxygen jet blows away the slag enabling the jet to pierce through the material and continue to cut through the material.

There are four basic requirements for oxy-fuel cutting: the ignition temperature of the material must be lower than its melting point otherwise the material would melt and flow away before cutting could take place the oxide melting point must be lower than that of the surrounding material so that it can be mechanically blown away by the oxygen jet the oxidation reaction between the oxygen jet and the metal must be sufficient to maintain the ignition temperature a minimum of gaseous reaction products should be produced so as not to dilute the cutting oxygen

As stainless steel, cast iron and non-ferrous metals form refractory oxides ie the oxide melting point is higher than the material, powder must be injected into the flame to form a low melting point, fluid slag.

Purity of oxygen

The cutting speed and cut edge quality are primarily determined by the purity of the oxygen stream. Thus, nozzle design plays a significant role in protecting the oxygen stream from air entrainment.

The purity of oxygen should be at least 99.5%. A decrease in purity of 1% will typically reduce the cutting speed by 25% and increase the gas consumption by 25%.

Choice of fuel gas

Fuel gas combustion occurs in two distinct zones. In the inner cone or primary flame, the fuel gas combines with oxygen to form carbon monoxide and hydrogen which for acetylene, the reaction is given by $2C2H2 + 2O2 \rightarrow 4CO + 2H2$

Combustion also continues in the secondary or outer zone of the flame with oxygen being supplied from the air. $4CO+2H2 +3O2 \rightarrow 4CO2 +2H2O$

Thus, fuel gases are characterized by their flame temperature - the hottest part of the flame is at the tip of the primary flame (inner cone) fuel gas to oxygen ratio - the amount of fuel gas required for combustion but this will vary according to whether the flame is neutral, oxidizing or reducing heat of combustion - heat of combustion is greater in the outer part of the flame

The five most commonly used fuel gases are acetylene, propane, MAPP (methyl acetylene propadiene), propylene and natural gas. The properties of the gases are given in the Table. The relative performance of the fuel gases in terms of pierce time, cutting speed and cut edge quality, is determined by the flame temperature and heat distribution within the inner and out flame cones.

Acetylene

Acetylene produces the highest flame temperature of all the fuel gases. The maximum flame temperature for acetylene (in oxygen) is approximately 3,160°C compared with a maximum temperature of 2,828°C with propane. The hotter flame produces more rapid piercing of the materials with the pierce time being typically one third that produced with propane.

The higher flame speed (7.4m/s compared with 3.3m/s for propane) and the higher calorific value of the primary flame (inner cone) (18,890kJ/m3 compared with 10,433 kJ/m3 for propane) produce a more intense flame at the surface of the metal reducing the width of the Heat Affected Zone (HAZ) and the degree of distortion.

Propane

Propane produces a lower flame temperature than acetylene (the maximum flame temperature in oxygen is 2,828°C compared with 3,160°C for acetylene). It has a greater total heat of combustion than acetylene but the heat is generated mostly in the outer cone (see Table). The characteristic appearance of the flames for acetylene and propane are shown in Figs.2 and 3 where the propane flame appears to be less focused. Consequently, piercing is much slower but as the burning and slag formation are effected by the oxygen jet, cutting speeds are about the same as for acetylene.

Propane has a greater stoichiometric oxygen requirement than acetylene; for the maximum flame temperature in oxygen, the ratio of the volume of oxygen to fuel gas are 1.2 to 1 for acetylene and 4.3 to 1 for propane.

Propylene

Propylene is a liquid petroleum gas (LPG) product and has a similar flame temperature to MAPP (2896°C compared to 2,976°C for MAPP); it is hotter than propane, but not as hot as acetylene. It gives off a high heat release in the outer cone (72,000kJ/m3) but, like propane, it has the disadvantage of having a high stoichiometric fuel gas requirement (oxygen to fuel gas ratio of approximately 3.7 to 1 by volume).

Natural Gas

Natural gas has the lowest flame temperature similar to propane and the lowest total heat value of the commonly used fuel gases, eg for the inner flame 1,490kJ/m3 compared with 18,890kJ/m3 for acetylene. Consequently, natural gas is the slowest for piercing.

Self-check. 3.

PART ONE:-say true or false and circle the correct answer.

1. Salt tablets should be taken when working in hot, sweaty conditions.
2. Operators must wear clothing made from industrial strength, heavy drill cotton.
3. A shade 6 filter lens is recommended for general cutting, gouging and heating applications.
4. Flame cutting and gouging emits ultraviolet light rays.
5. Operators must wear a respirator when natural or forced ventilation is inadequate.
6. In thermal cutting process it is possible to light the torch using matches.
7. Acetylene produces the lowest flame temperature of all the fuel gases.
8. The thickness of the material to be cut governs the selection of the tip.

PART ONE:-Choose the best answer

1. one of the following is not the requirements of thermal cutting can be categorized on___.

   A. The energy carrier C. Application of the cut part

   B. Type of production D. Color of material to be cut

2. One of the following is a type of material which cannot be cut by thermal cutting process?

   A. nonferrous B. Ferrous C. Plastic D. A and B

3. _________ is the slowest for piercing operation.

   A. Natural gas B. Acetylene gas C. Propane D. oxygen gas

4. Which one of the following is not a safety precaution in Cutting operations?

   A. Sweep floors clean before cutting C. use a cutting torch where sparks will be a hazard

   B. Never cut near ventilators D. Wear welding gloves

5. To cut mild-carbon steel with the oxyacetylene cutting torch, you should adjust the preheating flames to _____

   A. Carburize B. oxidize C. neutral D. all

PART THREE:-Match Column "A" with Column "B"

"A"	"B"
1. Flame to strong and Excess oxygen flame	A. Beaded cut edges
2, Nozzle-to-plate distance too small	B. Rounded cut edges
3. Gouging especially in bottom part	C. Travel too slow
	D. Current too high

PART FOUR: Review questions

These questions have been included to help you revise what you have learnt in Topic 1: Cutting, gouging and heating safety. 1. List five (5) hazards associated with cutting, gouging or heating.

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2. List six (6) items of protective clothing and equipment operators are required to wear when cutting, gouging or heating.

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3. List two (2) examples where fumes are generated as a result of cutting, gouging or heating.

____

____

4. Who in the workplace is responsible for issuing a "safe work" or "hot work" permit?

____

5. Explain how hot metal is indicated as a danger to others working nearby.

____

____

____

Unit Four: Quality and Clean Up
This learning guide is developed to provide you the necessary information regarding the following content coverage and topics: ➢ Measure Shape/size/length ➢ Clean, check, maintain, disposing and store Tools and equipment This guide will also assist you to attain the learning outcomes stated in the cover page. Specifically, upon completion of this learning guide, you will be able to: ➢ Measuring shape/size/length with acceptable standards Clean ➢ Cleaning, checking, maintaining, disposing and storing Tools and equipment

4. Quality and Clean Up

4.1. Shape/size/length is measured

4.1.1. Cut and shape materials using thermal cutting equipment

Performance evidence required you must be able to:

1. Work safely at all times, complying with health and safety legislation, regulations

2. Confirm that the equipment is safe and fit for purpose, by carrying out all of the following

   - the equipment selected is suitable for the operations to be performed
   - regulators, hoses and valves are securely connected and free from leaks and damage
   - the correct gas nozzle is fitted to the cutting torch
   - a flashback arrestor is fitted to the gas equipment
   - appropriate gas pressures are set
   - the correct procedure is used for lighting, adjusting and extinguishing the cutting flame
   - hoses are safely routed and protected at all times
   - gas cylinders are handled and stored safely and correctly

3. Plan the thermal cutting activities before you start them.

4. Following form of material (metal of 3mm and above):

   - plate plus one more from the following:
   - rolled sections
   - pipe/tube
   - Structures.

5. Produce cut profiles for one type of material from the following:

   - mild steel
   - high tensile/special steel
   - stainless steel
   - Other appropriate metal.

6. Obtain the appropriate tools and equipment for the cutting operations, and check that they are in a safe and usable condition

7. Set up the thermal cutting equipment for the operations to be performed.

8. Use the following thermal cutting method:

- hand-held oxy-fuel gas cutting equipment plus one more from the following:
- hand-held plasma gas cutting equipment
- simple, portable, track-driven cutting equipment (electrical or mechanical)
- Fixed bench gas cutting equipment.

9. Where appropriate, mark out the components for the required operations, using appropriate tools and techniques.
10. Operate the thermal cutting equipment to produce items/cut shapes to the dimensions and profiles specified.

11. Perform thermal cutting operations, to include all of the following:
   - Down-hand straight cuts (freehand)
   - cutting regular shapes
   - making radial cuts plus three more from the following:
   - making straight cuts (track guided)
   - making vertical cuts
   - making overhead cuts
   - cutting irregular shapes
   - making angled cuts
   - cutting chamfers
   - gouging/flushing
   - beveled edge – weld preparations
   - cutting out holes

12. Measure and check that all dimensional and geometrical aspects of the component are to the specification.

13. Produce thermally-cut components which meet all of the following:

   - dimensional accuracy is within the tolerances specified on the drawing/specification, or within +/- 3mm
   - angled/radial cuts are within specification requirements
   - Cuts are clean and smooth, without adhering dross and with minimal drag lines.

14. Deal promptly and effectively with problems within your control, and seek help and guidance from the relevant people if you have problems that you cannot resolve.

15. Shut down the equipment to a safe condition on conclusion of the machining activities.

16. Leave the work area in a safe and tidy condition on completion of the thermal cutting activities.

4.2. Safe Working Practices

This section describes safe practices developed from experience in using welding and cutting equipment. Continuous research, development, and field experience result in reliable equipment and safe installation, operation, and servicing practices. Accidents occur because of improper equipment use or maintenance. Some safe practices are based on common sense; others may require technical volumes to explain. In any event, rules should be followed.

Work Area

The work area must have a fireproof floor. Concrete is best;

- Use heat resistant shields to protect walls and unprotected flooring from sparks and hot metal;
- Oxygen itself will not burn; however, the presence of pure oxygen will accelerate combustion and cause materials to burn with great intensity;
- Use tables with fireproof tops. Firebricks work well to protect table and bench surfaces;
- Chain or otherwise secure cylinders to a wall, bench or cart;
- Keep the area between you and the cylinder valves unobstructed;
- Keep cylinders clear of areas where they may be struck or knocked over.
- Post “No Smoking” warning sign in area.

Hazardous Fume Accumulation & Ventilation

Maintain adequate ventilation to prevent the accumulation of toxic fumes and gases; (Refer to ANSI Standard Z49-1); Work in a confined space only while it’s being ventilated, or when wearing an air supplied respirator. Do NOT use oxygen for ventilation.

Protective Clothing

Wear protective clothing – gauntlet gloves, hat, and high safety toe shoes. Keep shirt collar and pocket flaps buttoned and wear cuffless trousers to prevent entry of sparks and slag. Hot metal such as welding rod, electrode stubs and work pieces should never be handled without gloves; Wear safety goggles or glasses with side shields, appropriate filter lenses or plates (protected by clear cover glass). This is a MUST for welding or cutting (and chipping), to protect the eyes from radiant energy and flying metal. Replace cover glass when broken, pitted, or spattered. For eye protection refer ANSI Z 87.1; Do not wear oily or greasy clothing while welding or cutting. They are readily ignited by sparks; Wear ear protection when working overhead or in a confined space. A hard hat should be worn when others work overhead.

Fires and Explosions

Fire or explosion can occur if the equipment is improperly installed, repaired or used. Be aware that: flying sparks or falling slag can pass through cracks, along pipes, through windows or doors, and through wall or floor openings, out of sight of the goggled operator. Sparks and slag can fly 35 feet; Inspect oxy-fuel apparatus for oil, grease, or damaged parts; Do not use the oxy-acetylene apparatus if oil or grease is present or if damage is evident; Never use oil or grease on or around any oxy-acetylene apparatus; Keep flames, heat and sparks away from cylinders and hoses; Have a fire extinguisher of proper type and size on hand in the work area, know where they are located in the shop; Open the oxygen valve all the way to seal the cylinder back seal packing;

Never test for leaks with a flame. Use soapy water; after work is complete, inspect the area for any possible fires or smoldering materials.

Fuel Leakage and Detection

Joints and hoses should be checked for leaks before any welding is attempted. Whilst acetylene may be detected by its distinctive smell (usually at levels of less than 2%) oxygen is odorless;

Leak detection is best carried out applying a weak (typically 0.5%) solution of a detergent in water or a leak detecting solution from one of the gas supply companies. It is applied to the joints using a brush and the escaping gas will form bubbles. On curing the leak, the area should be cleaned to remove the residue from the leak detecting solution.

Use of Oxygen

Always refer to oxygen by correct name; Say “oxygen”, never “air”. It is very important that oxygen not be confused with compressed air, or used as a substitute for compressed air; Oxygen is not flammable but even materials that do not burn in air usually burn in oxygen. Those that burn slowly in air can ignite easily and burn violently in an oxygen enriched atmosphere; Never use oxygen to ventilate confined spaces. Use air to replace atmospheric oxygen consumed by welding or cutting. Oxygen-enriched (> 23%) or oxygen depleted (<19%) atmospheres should be avoided; Never saturate clothes with oxygen. Clothing saturated with oxygen will burn intensely when ignited; Grease, oil, oil-bearing materials, greasy gloves and rags, and other combustibles that can readily ignite in the presence of oxygen must be kept from any oxygen equipment; Keep oxygen cylinders at least 20 feet from fuel gas cylinders or other readily combustible materials particularly grease or oil OR separated by a five foot noncombustible barrier having a fire resistance rating of at least ½ hour); If liquid oxygen is used, cylinders must be transported, stored and used in upright position to maintain gaseous state for safety devices, and to prevent liquid from reaching regulator.

Use of Acetylene Gas

Refer to fuel gas by its correct name. Say “acetylene”, not “gas”. The other gases- natural gas, methane, or the liquefied petroleum (LP) gases, propane and butane – differ from acetylene, and from each other, in heat content, flammability limits, and safe handling requirements. Therefore, be specific when you refer to any gas; Acetylene cylinders must be transported, stored, and used in upright position to avoid discharge of acetone with the gas during use; CGA 5.3.3.13 or G-1 calls for a withdrawal rate “not to exceed 1/10(one-tenth) of the capacity of the cylinder per hour during intermittent use. For full withdrawal of the contents of the cylinder on a continuous basis, the flow rate should be no more than 1/15 (one-fifteenth) of the capacity of the cylinder per hour”;

If cylinder valves leaks, immediately close valve on fuel gas cylinder. If valve still leaks immediately, remove cylinder outdoors, away from possible source of ignition and notify cylinder supplier at once;

Acetylene cylinder wrench should be left on an open cylinder valve and removed after closing valve. Use only approved wrench, available from cylinder supplier.

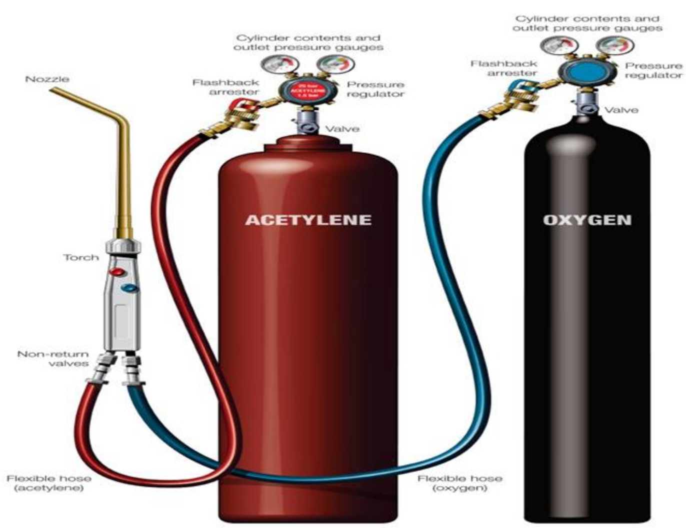

Fig.4.1. Two cylinders, Health and Safety Executive

Pressure regulators

NEVER withdraw gas from a cylinder or pipeline except through an approved pressure reducing regulator; Regulator relief valve is designed to protect only the regulator from overpressure; it is not intended to protect any downstream equipment. Provide such protection with one or more relief devices; Never connect a regulator to a cylinder containing gas other than that for which the regulator was designed; Remove regulator from cylinder when transporting unsecured on a cart not designed for such purpose; The following symptoms indicate a faulty regulator:

Leaks - if gas leaks externally. Excessive creep - if the regulator delivery pressure continues to rise with downstream valve closed.

Faulty gauge - if gauge pointer does not move off “stop” pin when pressurized, nor return to “stop” pin after pressure release.

Cylinders

Cylinders must be handled carefully to prevent leaks and damages to their walls, valves, or safety devices: a. Avoid electrical circuit contact with cylinders including third rails, electrical wires, or welding circuits. They can produce arcs that may damage the cylinder wall, causing a possibly serious accident. Never strike an arc on a cylinder; Identifying gas content; Use only cylinders with name of gas marked on them; do not rely on color of cylinder to identify contents. Notify supplier if content of cylinder is not clearly identifiable. Never deface or alter name, number, or other markings on a cylinder. It is illegal and hazardous;

Never use a cylinder or its contents for other than its intended use. Never use as a support, roller, or clothes rack; Secure from falling. Always chain or secure cylinders upright when a regulator (and hose) is connected to it; transporting cylinders. With a crane, use a secure support such as a platform or cradle designed for the purpose. Do NOT lift cylinders off the ground by their valves or caps, or by chains, slings, or magnets; Do NOT expose cylinders to excessive heat, sparks, slag, and flame, etc. that may cause rupture; Do not allow contents to exceed 130°F; Protect cylinders, particularly valves from bumps, falls, falling objects, and weather. Keep caps securely tightened on cylinders not in use or being moved.

Stuck valve. Do NOT use a hammer or metal wrench (except special key for acetylene) to open a cylinder valve that cannot be opened by hand. Notify your supplier; Cylinder fittings should never by modified or used for other than their intended purpose.

Torch

Examine seating surface of torch and connections before use for ear and damage. Worn or damaged parts should be replaced; Do not attempt repair of torches (or regulators). If faulty, send them for repair to manufacturer’s designated repair center where special techniques, tools and tests are used by trained personnel; Torch is not a hammer. Never use it to chip slag. Such misuse can distort torch or tip to create hazards. Use appropriate tool for the job; Torch tip cleaning should be done only with specifically-designed cleaning tip orifices to avoid enlarging or damaging the exit holes.

Hoses

NEVER use hose other than that designed for the specified gas. A general hose identification rule is: red for fuel gas, green for oxygen, and black for inert gases; Use RMA-CGA Grade T hose for fuel gas (including acetylene) to prevent hose failures. Grades R and RM are for use with acetylene only; Use ferrules or clamps designed for the hose (not ordinary wire or other substitute) to connect hoses to fittings; Use only standard brass fittings to splice hose. No copper tubing splices; Avoid long runs to prevent kinks and abuse. Suspend hose off ground or protect it from damage by vehicles, sparks, slag or open flames; Examine hose regularly for leaks, wear, and loose connections. Immerse pressured hose in water; bubbles indicate leaks; Repair leaky or worn hose by cutting out damaged area and splicing. Do NOT use tape.

Proper Connections

Clean cylinder valve outlet of impurities that may clog orifices and damage seats before connecting regulator; Match regulator to cylinder. Before connecting, be sure the regulator label and cylinders marking agree, and the regulator inlet and cylinder outlet connections are proper for the intended service;

Do not use pipe compound or lubricant. Tighten but do not force connection. If connection leaks, close cylinder valve, depressurize line. Disassemble, clean, and retighten the valve. For metal-to-metal seating, use correct wrenches, available form your supplier. For O-ring connections, hand tighten; avoid using adapters between cylinder and regulator, but if unavoidable, use a CGA adapter (available from your supplier). Use two wrenches to tighten adapter with both right and left hand threads; Regulator outlet (or hose) connections may be identified by right hand threads for oxygen and left hand threads (with grooved hex on nut or shank) for fuel gas.

4.3. Clean, check, maintain and store thermal cutting Tools and equipment

Before attempting to cut, the plate should be cleaned of dirt, paint, grease, oil, mud, mill bloom or scale and rust with a stiff wire brush or by scaping. Mill scale can often be readily removed by running the preheating flame over the line of the cut. Hold the inner cone of the preheating flame 3–5mm above the edge of the plate until it is heated to a bright red colour. Start the cut at the edge of the plate, when practicable, or pierce, as required.

4.3.1. Proper tool handling compressed gas Cylinders:

- No tampering with numbers or marks stamped
- Mechanical device advisable for carrying. They may be rolled on bottom edge, but never dragged.
- Never lift with electromagnet. For handling by crane or derrick cradle should be used.
- Never drop cylinders or allow them to strike each other violently.
- No misuse of cylinder.
- No tampering with safety devices
- Before returning empty cylinders positively mark they 'EMPTY' with chalk. Close valves and replace valve protection cap.
- Always consider cylinders full, if not definitely known. 9. When in doubt, ask supplier

4.3.2. Storage

- Keep away from radiators and all sources of heat.
- Inside building, cylinders in a well-protected well ventilated dry location, at least 20 feet away from highly combustible materials, such as oil. There should be definitely assigned place for storing away from elevators, stairs, and gang ways. Never keep at a place where these can be knocked over or damaged by passing or falling objects. Never store in unventilated enclosures, such as locker and cup-boards.
- Cylinders containing oxygen and combustible gases, such as acetylene, hydrogen should not be store in same room. If stored in the same room under unavoidable circumstances they be kept far apart (20 feet) a noncombustible barrier in between of at least 5 feet having a fire resistance rating of at least half-an-hour.
- Store Acetylene cylinder always upright,

Use

- Use cylinders in upright position and secure them against accidentally being knocked over.

- Keep metal cap in place to protect valve, when not connected for use.
- Do not force connections that do not fit.
- Open valves slowly. Use opening tool provided by supplier
- Do: not use a compressed gas cylinder without pressure reducing regulator device attached to the valve.
- Use regulators and pressure gauges only with gases only designed.
- Leaking cylinders must be taken out of use immediately, valve closed cylinder removed, outdoor and supplier notified.
- Do not permit any source of ignition to come in contact with the cylinder or attachment.
- Never use oil or grease as a lubricant on valves or attachment and do not handle cylinders with oily hands gloves or clothing's.
- Never use oxygen as a substitute for compressed air.
- Before removing a regulator from a cylinder valve, close the valve and release the gas from the regulator.

Self-Check -4

PART ONE: Say true or false

1. In thermal cutting the work area must have a fireproof floor.
2. It is possible to use oil or grease on or around any oxy-acetylene apparatus.
3. You can force connections that do not fit.
4. Always keep fuel gas cylinder near to radiators and all sources of heat.

PART TWO:-Choose the best answer

1. Thermal cutting operation is performed to_____________.

   A. Cut out holes C. cutting regular shapes
   B. cutting chamfers D. All

2. One of the following is not a protective clothing?, and high safety toe shoes

   A. Keep the work area clean B. gauntlet gloves C. hat D. high safety toe shoes

3. _________ can be occur if the equipment is improperly installed, repaired or used.

   A. Light B. Fire C. Explosion D. B and C

4. Which one of the following is a general hose identification rule for oxygen gas?

   A. Red B. Green C. Black D. Yellow

PART THREE: Match Column "A" with Column "B"

"A"	"B"
1. Right hand threads	A. Fuel gas
2, left hand threads	B. Tap
	C. Oxygen

Reference

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