STIERI

BASIC WELDING PRINCIPLES

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Contents

Part I

Oxy-Acetylene Welding and Cutting

Chapter 1

General Description of Welding and Cutting Processes

The processes involved for both oxy-acetylene welding and cutting are simple. They are based on two fundamental principles:

1. That acetylene burned with an equal amount of oxygen produces an intensely hot flame that will melt and fuse most metals.

2. That a jet of oxygen striking a piece of iron or steel that has been heated to its established kindling temperature, causes the metal to burn rapidly away.

General Description of Oxy-Acetylene Welding

Oxy-acetylene welding, in principle, is fundamentally simple. Two pieces of metal are brought together and the edges in contact are melted by the oxy-acetylene flame, with or without the addition of molten metal from a welding rod. The molten edges flow together until each is completely fused with the other. After the metal has cooled the result will be a single, continuous seamless piece. Specific rules for practical applications are given in subsequent chapters, and, of course, cannot be stated so easily, but the art of oxy-acetylene welding nevertheless retains this essential simplicity.

Fusion-welding. Welds made in the manner just described are called *fusion welds* because the base [illegible] is actually melted and fused, frequently with [illegible] from the welding rod. In fusion-welding, the base metal and the welding rod should have, in most cases, essentially the same composition. For example, in fusion-welding cast iron, a cast iron welding rod is used. Cast iron, wrought iron, plain carbon steel, cast steel, alloy steel, stainless steel, copper, brass, bronze, aluminum, aluminum alloys, nickel, nickel alloys, magnesium alloys, and lead are all joined by the oxy-acetylene fusion-welding process.

Bronze-welding. Bronze-welding is a method for producing strong joints in metals having melting points higher than that of the bronze welding rod used. In bronze-welding, the edges of the joint are heated to a dull red by the oxy-acetylene blowpipe flame. With the base metal at the proper temperature and with the aid of a specific and suitable flux, molten bronze from a bronze welding rod will unite with the base metal to form a strong bond. A properly made bronze weld is quite comparable in strength to a true fusion weld, and will have tensile strengths that may be as high as 50,000 lb. per sq. inch.

Bronze-welding is widely used for joining cast iron, malleable iron, wrought iron, galvanized iron, carbon steels, cast steel, copper and copper alloys, nickel and nickel alloys. It is also valuable for joining dissimilar metals such as steel and copper or malleable iron.

Bronze-surfacing. The term bronze-surfacing is applied to the operation of building up metal surfaces with bronze welding rods. The operation, of course, is similar to bronze-welding, but here the object is the building up of the surface rather than the joining of two parts, and special wearing bronze may be used.

Hard-facing. The life of metal parts subjected to extreme wear or abrasive action can be greatly increased by applying a coating of a suitable hard-facing alloy. There are several such alloys on the market, all of which are available in the rod form and are easily applied to the base metal by means of the oxy-acetylene blowpipe flame. In hard-facing with these alloys the base metal is brought merely to a specified temperature, as it is essential to keep at a minimum the intermingling of base metal and hard-facing alloy. Excessive intermingling would tend to reduce the efficiency of the hard-facing material.

Brazing and Hard-soldering. Although brazing and hard-soldering are not true welding operations, they are methods sometimes used for joining metals. The oxy-acetylene welding blowpipe is used frequently in brazing operations where the brazing material is in the form of spelter. Spelter is a form of granulated brass. The oxy-acetylene welding blowpipe can also be used effectively in hard-soldering the solder-type fittings for copper pipe that is to be used at temperatures in which the soft solder ordinarily used with these fittings would not be satisfactory, for conditions requiring greater joint strength than that provided by soft solder, or for corrosion-resistant joints.

General Description of Oxy-Acetylene Cutting

Oxygen cutting is similar to the eating away of steel by ordinary rusting, but much faster. In rusting, the oxygen—in the air or in water—affects the metal slowly. Directing a jet of oxygen at metal heated almost to the melting point actually speeds up rusting, and burns away the metal. The iron oxide melts and runs off as molten slag, exposing more iron to the action of the oxygen jet. This makes it possible to cut iron and steel, leaving a smooth, narrow cut.

Fundamental Principle of Cutting. If a piece of steel wire is heated to a red temperature and thrust into a bottle of pure oxygen, it will burn vigorously. This elementary chemistry experiment illustrates the scientific principle that forms the basis of oxy-acetylene cutting. Above a red heat, iron combines with pure oxygen so rapidly that it actually *burns*. Thus, if a spot on a piece of iron or steel is heated to the kindling temperature and a jet of oxygen is directed at the heated spot, the iron will begin to burn vigorously. Heat is generated, just as the burning of a piece of wood produces heat.

Preheating Flames. It might appear at first thought that the heat generated by the burning iron should be sufficient to bring adjacent iron to a red heat so that, once started, the cut could be continued indefinitely with only oxygen. Practically, however, radiation at the surface, on pieces of dirt, paint, or scale on the metal plus the fact that heat is conducted away into the relatively cold metal beside the cut, make it necessary for additional heat to be supplied to continue the cut. Therefore, the cutting blowpipe has a number of small orifices for oxy-acetylene heating flames surrounding a central opening that supplies the oxygen jet.

In making a cut, these preheat flames are used to heat a spot to a red heat. The cut is then started by opening the valve controlling the oxygen jet and directing the stream of oxygen at the heated spot. The preheating flames remain burning while cutting is in progress to make up for the heat that is lost during the operation, as explained in the previous paragraph.

Machine Flame-cutting. Though a considerable amount of oxy-acetylene cutting is done freehand with a hand-cutting blowpipe, greater precision of cutting is obtained when blowpipes are mounted in machines. Cutting machines of various types are available. Perhaps the simplest type is the straight-line cutting machine, used for trimming or beveling the edges of steel plate. Special machines have been developed for such operations as cutting rounds and billets, and cutting and beveling pipe. The peak of this machine flame-cutting is reached in the shape-cutting machine, by means of which regular or irregular shapes of almost any size or thickness can be cut. In these machines, the cutting blowpipe usually is guided automatically, thereby allowing the production of any number of identical parts.

Flame-gouging. Flame gouging was developed originally for removing surplus metal from the underside of welds and for removing weld defects revealed by visual or X-ray inspection—operations which normally involve a great deal of chipping with pneumatic hammers. The immediate success of the gouging blowpipe for this type of work soon led to its use for many maintenance operations and for the preparation of plate edges for welding.

Briefly, gouging provides a means for quickly and accurately removing a narrow strip of surface metal from steel plates, forgings, and castings. The principle of the process is based on the fact that the nozzle is designed to deliver a relatively large jet of oxygen at low velocity. If the oxygen jet is properly manipulated, a smooth, accurately defined groove can be cut or gouged out of the surface of the metal. By using different nozzles and manipulations, the groove can be varied in width and depth to suit the operation.

RAPID REVIEW

1. In fusion-welding two pieces of metal are brought together and the edges in contact are melted and fused with or without the addition of molten metal from a suitable welding rod.

2. Bronze-surfacing is a method used for building up metal surfaces with bronze welding rods.

3. Where greater joint strength than that provided by soft solder is required, or for corrosion-resistant joints, the oxyacetylene welding blowpipe can be used effectively in hard-soldering the solder-type fittings for copper pipe.

4. In flame-cutting machines of various types the cutting blowpipes are usually automatically guided; thus production of any number of identical parts is made possible.

Chapter 2

Tools and Equipment

Cylinders

To make the oxy-acetylene process available, convenient sources of oxygen and acetylene in safe and standardized containers are essential. Technical details of manufacture and distribution methods have been perfected until supplies of these gases can now be obtained in every part of the country.

OXYGEN CYLINDERS (Fig. 1). Oxygen cylinders are shipping containers for gas, and are therefore subject to the rules and requirements of the Interstate Commerce Commission and other regulatory bodies. This is one reason why the cylinders are not sold. By retaining ownership of the cylinders, the oxygen company assumes all responsibility for complying with the various regulations and thus relieves the user of much unnecessary bother and expense.

Valves. Each cylinder must have a valve specially designed to operate at high pressures. The oxygen-cylinder valve shown in Fig. 2 has a double seat, the second seat having the function of preventing leakage around the valve stem when the valve is fully opened. When in use, the valve should always be opened as far as it will go. A fairly strong grip on the handwheel is all that is required to open or close it. A wrench should not be used.

An iron cap that screws on the neck ring of the cylinder protects the valve from damage during shipment and handling. Except when the cylinder is in use, this protecting cap should be in place.

Pressure in an Oxygen Cylinder. Cylinders are charged with oxygen at a pressure of 2,200 lb. per sq. in. at 70 deg. F. All gases expand when heated and contract when cooled; the pressure of oxygen in the closed cylinder increases and decreases as the temperature changes, since the cylinder volume remains constant. If, for example, a full cylinder of oxygen is allowed to stand outdoors for several hours when the temperature is 30 deg. F., or just below freezing, the pressure of the oxygen will register approximately 2,000 lb. per sq. inch. This does not mean that any oxygen has been lost; cooling the oxygen has merely reduced its pressure. Placing the cylinder in a warm room of 70 deg. F. will bring the pressure back to 2,200 lb. Here again, no oxygen has been gained, warmth has merely increased the pressure.

When the temperature goes above 70 deg. F., the pressure in a full cylinder will rise above 2,200 lb. per sq. inch. To provide against dangerously excessive pressures, such as might occur if the cylinder were directly exposed to fire, every cylinder valve has a safety nut containing a disk of special metal that will burst if the pressure gets too high. Consequently, oxygen cylinders should not be stored or used where they might become overheated. Should this happen, the safety disk will break and the oxygen will be lost.

Size and Weight. The high charging pressure makes it possible to put 244 cu. ft. of oxygen into a cylinder about 56 in. tall (including the valve-protecting cap) and with a diameter of about 9 in.;

122 cu. ft. of oxygen into a cylinder with a height of about 48 in. and a diameter of 7 in.; and 80 cu. ft. of oxygen into a cylinder 35 in. tall and about 7 in. in diameter. These are the three sizes commonly used for welding and cutting. The 244 cu. ft. cylinder weighs approximately 152 lb. full and 133 lb.

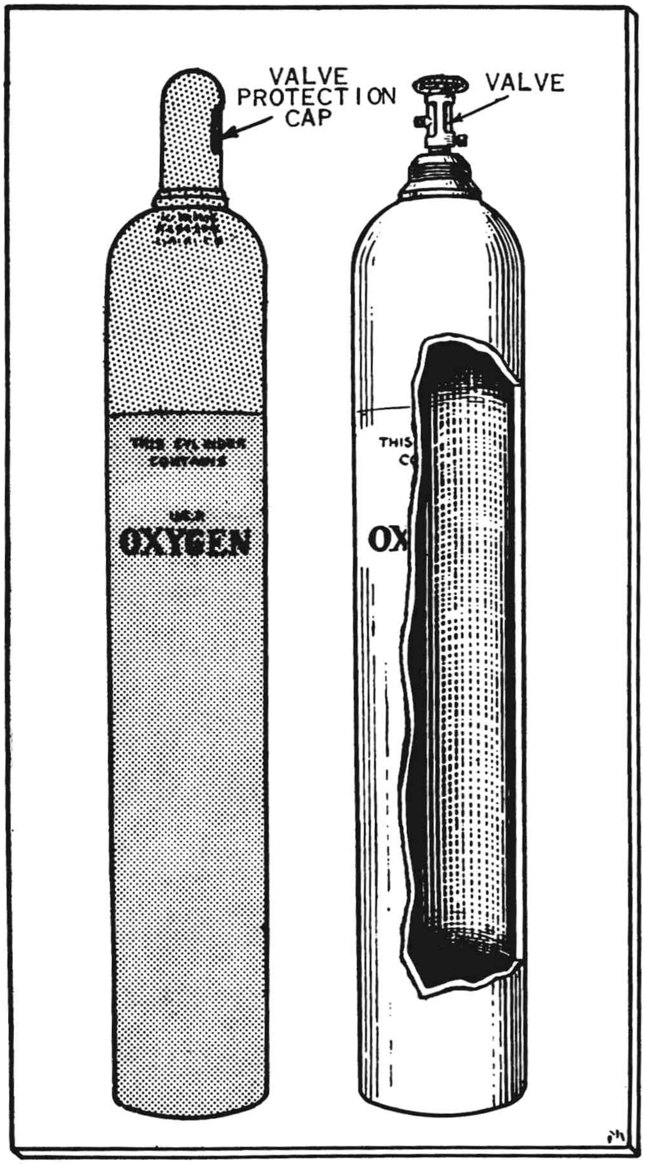

Figure 1.

empty. The average weight of 122 cu. ft. cylinder is 89 lb. full and 79 lb. empty. The 80 cu. ft. cylinder weighs about 67 lb. full and 60 lb. empty.

Safety Precautions. When cylinders leave the charging plant or warehouse they are in proper condition and safe for the purpose intended. It is necessary to prevent abuse of cylinders on the job to keep them in this safe condition.

Regulations of the National Board of Fire Underwriters and any local, state, and municipal regulations regarding cylinder storage should be followed closely.

While cylinders are being moved, keep them from being knocked over or from falling. When moving cylinders by crane or derrick, use a suitable cradle, boat, or platform. Never use slings or an electric magnet. Whenever practicable, suitable trucks should be provided for conveying and handling cylinders.

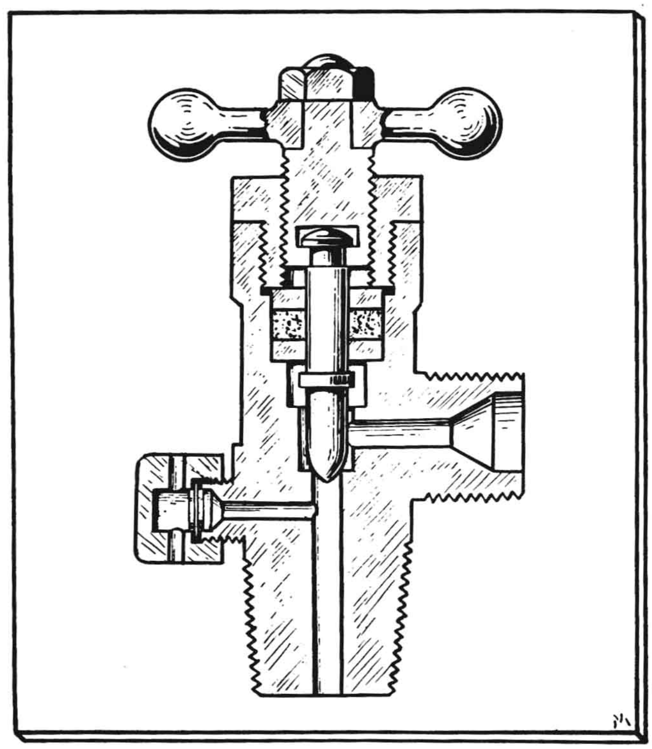

Figure 2. Cross-section of a double-seated oxygen cylinder valve.

Unless cylinders are on a suitable truck, regulators should be removed and valve-protection caps should be put in place hand-tight when cylinders are moved. Always close cylinder valves before moving cylinders.

Never use valve-protection caps for lifting cylinders from one vertical position to another. It is not good practice to allow cylinders to lie in a horizontal position.

Never use cylinders as rollers or supports even if they are considered to be empty.

Keep cylinders from being knocked over while in *use.* Use a suitable truck, chain, or other steadying device.

Never allow cylinders to come in contact with live wires, third rails, or ground wires from electrical equipment.

Keep cylinders far enough away from welding or cutting work so that sparks, hot slag, or flame will not reach them.

Always close cylinder valves when work is finished, and always close valves of empty cylinders while in storage prior to return and while being returned to the supplier. Return empty cylinders promptly to the supplier. Keep empty cylinders separate from full cylinders to avoid confusion, and use full cylinders in the order received from the supplier. When returning empty cylinders to the supplier by freight or express, forward the original bill of lading promptly.

General Maintenance of Oxygen Cylinders. Always call oxygen by its proper name—"oxygen." Never use oxygen in place of compressed air. Oxygen should never be called "air" and should never be confused with compressed air. Oxygen should never be used in pneumatic tools, in oil preheating burners, to start internal combustion engines, to blow out pipe lines, to "dust" clothing or work, for pressure tests of any kind, or for ventilation. Oxygen, or air rich in oxygen, should never be allowed to saturate any part of the clothing because a spark might quickly start a fire.

Keep oxygen cylinder fittings away from oil or grease: Oil or grease may ignite violently in the presence of oxygen under pressure. Oily or greasy substances must be kept away from cylinders, cylinder valves, couplings, regulators, hose, and apparatus. Do not handle oxygen cylinders or apparatus with oily hands or gloves. Oxygen cylinders should not be handled on the same platform with oil or placed in a position where oil or grease from overhead cranes or belts is likely to fall upon them. A jet of oxygen should never strike an oily surface or greasy clothes, or enter a fuel-oil or storage tank that has contained a flammable substance. Oxygen will not burn, but it supports and accelerates combustion, and will cause oil and other similar material to burn with great intensity.

Never tamper with or attempt to repair oxygen cylinder valves. If trouble occurs, tag the cylinder and promptly send the supplier a full report on the character of the trouble, giving the serial number stamped on the cylinder. Follow his instructions for its prompt return.

ACETYLENE CYLINDERS. Acetylene is widely distributed in cylinders, but these are quite different in construction from oxygen cylinders. The supplier obtains safety and capacity by packing the acetylene cylinders with a porous material, and filling the fine pores with acetone, a liquid chemical having the property of dissolving or absorbing many times its own volume of acetylene. In such cylinders acetylene is perfectly safe and will not change its nature.

Valves. The cylinder itself is a strong steel container completely full of the porous substance which in turn is saturated with the acetone. Acetylene is drawn off through a valve which, in the type shown in Fig. 3, is located in a recessed top where it is protected from breakage. Since the valve does not have to withstand such high pressures as does an oxygen valve, it is much simpler in construction. The valve is operated by means of a key handle which should be left in place during use of the cylinder. The valve should be opened only one and one-half turns. Safety fuse plugs are provided in acetylene cylinders to meet any fire emergency, and the entire cylinder construction must satisfy the requirements of the Interstate Commerce Commission.

Size and Weight. Dissolved acetylene is sold in cylinders, the most common sizes having rated capacities of 60, 100 or 300 cu. ft. The actual acetylene content of these cylinders averages somewhat below the rated capacity, but the customer is billed only for the actual acetylene content of the particular cylinder shipped. Average shipping weights are: for the 60 cu. ft. cylinders, 55 lb. full, 51 lb. empty; for the 100 cu. ft. cylinders, 97 lb. full, 90 lb. empty; for the 300 cu. ft. cylinders, 240 lb. full, 223 lb. empty. A pressure gauge placed on a full cylinder containing dissolved acetylene would register approximately 225 lb. per sq. inch.

Safety Precautions. In storing cylinders, remember that acetylene is a fuel gas. Since acetylene will burn, acetylene cylinders must be kept away from fire. They should not be stored near stoves, radiators, furnaces, or other sources of heat, and should be stored well away from highly combustible materials such as oil or excelsior. Locations for storing acetylene cylinders should be well protected, ventilated, and dry. In special buildings, rooms, or compartments used for storing acetylene cylinders, ventilation should be given special attention.

Avoid rough handling, dropping, or knocking acetylene cylinders. The fusible safety plugs with which all acetylene cylinders are provided act as a safety release when the cylinder is exposed to excessive temperatures. The plugs melt at about the temperature of boiling water and release acetylene from the cylinder. Rough treatment might damage the fuse plugs, the cylinder, or the valve.

Should the valve outlet on an acetylene cylinder become clogged with ice, thaw with warm—not boiling—water. Since the fusible safety plugs with which all acetylene cylinders are provided melt at about the temperature of boiling water, the valve outlet should be thawed only by applying warm water to the valve. Never use a flame for this purpose.

Never use a cylinder that is leaking acetylene. If acetylene leaks around the valve spindle when the valve is open, close the valve, and tighten the packing nut. This compresses the packing around the spindle. If this does not stop the leak, close the valve, and attach to the cylinder a tag stating that the valve is unserviceable. Notify the supplier and follow his instructions for the return of the cylinder.

If the acetylene leaks from the valve even when it is closed, or if rough handling should cause any of the fusible safety plugs to leak, move the cylinder to a place out-of-doors and well away from any possible source of ignition, and tag it plainly as having an unserviceable valve or fuse plug. Open the valve slightly to let the acetylene escape slowly. Place a sign at the cylinder warning anyone against coming near with a lighted cigarette or other source of ignition. When the cylinder is empty, close the valve and move the cylinder to a suitable location awaiting shipment. Notify the supplier and follow his instructions for the further handling and return of the cylinder.

Do not open an acetylene cylinder valve more than one and one-half turns. On acetylene cylinders of the type shown in Fig. 3 the special T-wrench or key for opening or closing the cylinder valve should be used. Always leave the T-wrench or key in position ready for immediate use, so that the acetylene can be turned off quickly in case of emergency. If this wrench is lost, a new one can be obtained from the acetylene supplier.

Opening acetylene cylinder valves one and one-half turns permits an ample flow of acetylene. When a regulator is attached, always open the cylinder valve very slightly at first to avoid damaging the regulator mechanism or gauges. Always stand away from the front of the regulator and gauge faces when opening these cylinder valves. Do not use the recessed top of the cylinder as a place for tools, since this might interfere with the quick closing of the valve or damage the fusible safety plugs.

Use acetylene cylinders only in the normal way. For example, never use acetylene from a cylinder except through an acetylene regulator, and never under any circumstances attempt to transfer acetylene from one cylinder to another, or to refill acetylene cylinders, or to mix any other gas with the acetylene in a cylinder.

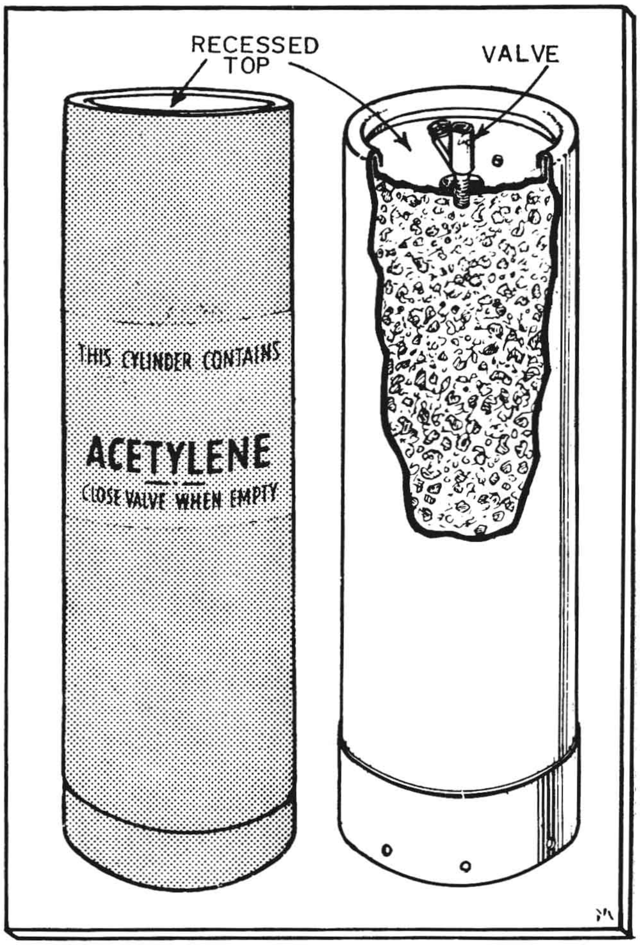

Figure 3.

Generators

Where large amounts of acetylene are required at specified points in the plant, it is both economical and practical to make the acetylene on the spot using calcium carbide, or "carbide" as it is known in the trade, and a suitable type of generator.

When carbide is dropped into water, a reaction occurs that causes bubbles of gas to rise. This gas has a peculiar odor and, if lighted, burns with a smoky

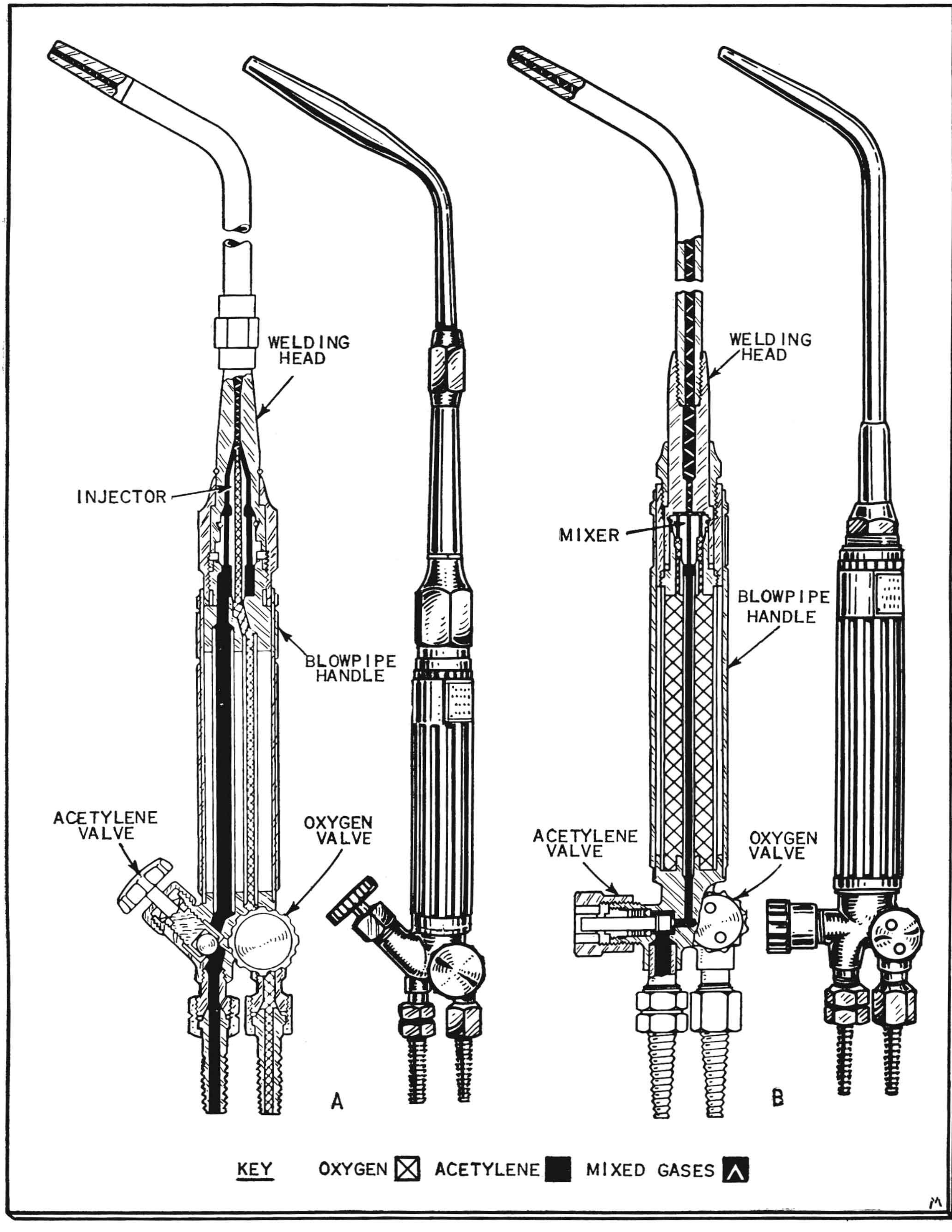

Figure 4. (A) A typical injector-type welding blowpipe. (B) A typical medium-pressure-type welding blowpipe.

flame. After the action has stopped and no more gas is given off, a whitish residue remains in the water. The gas is acetylene and the residue is hydrated or slaked lime (calcium hydroxide).

Since acetylene burns and, like any other combustible gas, forms explosive mixtures with air, it is clear that acetylene should not be produced for any purpose in makeshift or homemade equipment. Only a suitable generator bearing the Re-examination Service Marker of the Underwriters' Laboratories, Inc., and the Mark of Approval of the Factory Mutual Laboratories should be used.

Blowpipes (Welding)

The function of a welding blowpipe is to provide a means for mixing approximately equal amounts of oxygen and acetylene, and to provide the required quantity of this gas mixture at the blowpipe tip so that, when ignited, a flame of the size and character desired will be produced. While blowpipes vary widely in design, basically all approved types are equipped to give the mechanic complete control over the size and characteristics of the flame. A wide range of welding heads or tips are available. They are used in connection with the standard blowpipe to provide mixing chambers and gas orifices of varied sizes so that a large number of flame sizes can be secured.

Classification of Welding Blowpipes. The construction and operating principles of oxy-acetylene blowpipes are such that all of these blowpipes fit into either of two general classes, the injector or the medium pressure type, depending upon the acetylene pressure used.

The injector-type can use acetylene at pressures of even less than 1 lb. per sq. in., while medium-pressure types require that the acetylene be supplied at pressures from 1 to 15 lb. per sq. inch.

Injector-type blowpipes can use acetylene from low-pressure generators, medium-pressure generators, or cylinders. Medium-pressure blowpipes can be used with medium-pressure generators or with cylinders, but not with low-pressure generators.

In the injector-type blowpipe oxygen passes through a small opening in the injector nozzle, producing a suction effect which draws acetylene into the oxygen stream. One advantage of this type of construction is that small fluctuations in the amount of oxygen supplied to the blowpipe will produce a corresponding change in the amount of acetylene drawn into the gas mixture, so that proportions of the two gases remain substantially constant while the blowpipe is in operation.

In medium-pressure blowpipes, oxygen and acetylene are fed at independent pressures to a mixer nozzle, the construction of which varies considerably according to the ideas of the different manufacturers.

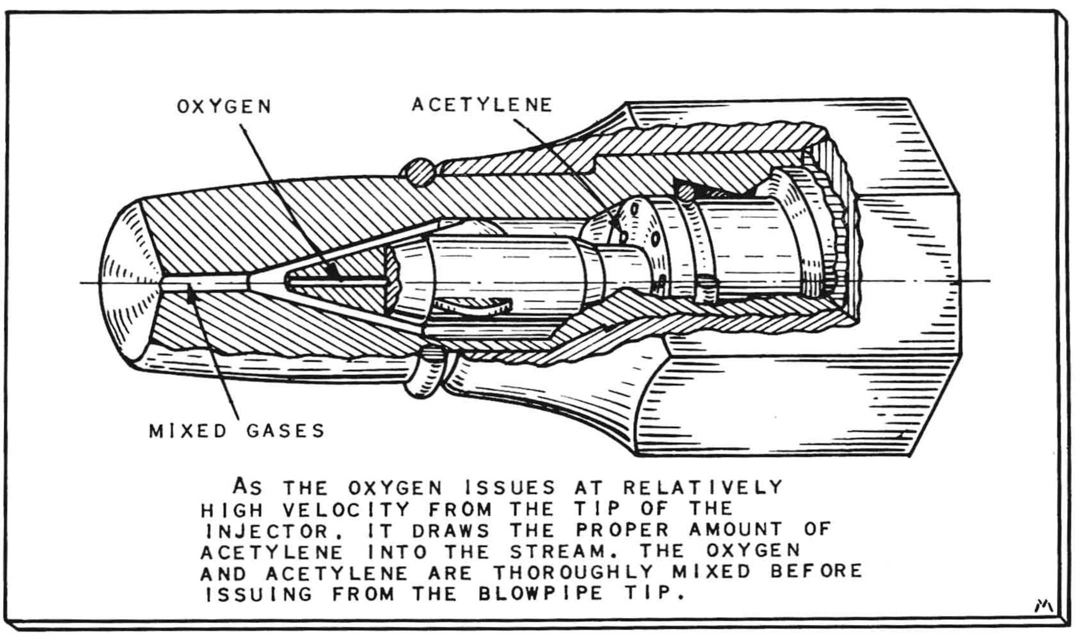

Figure 5.

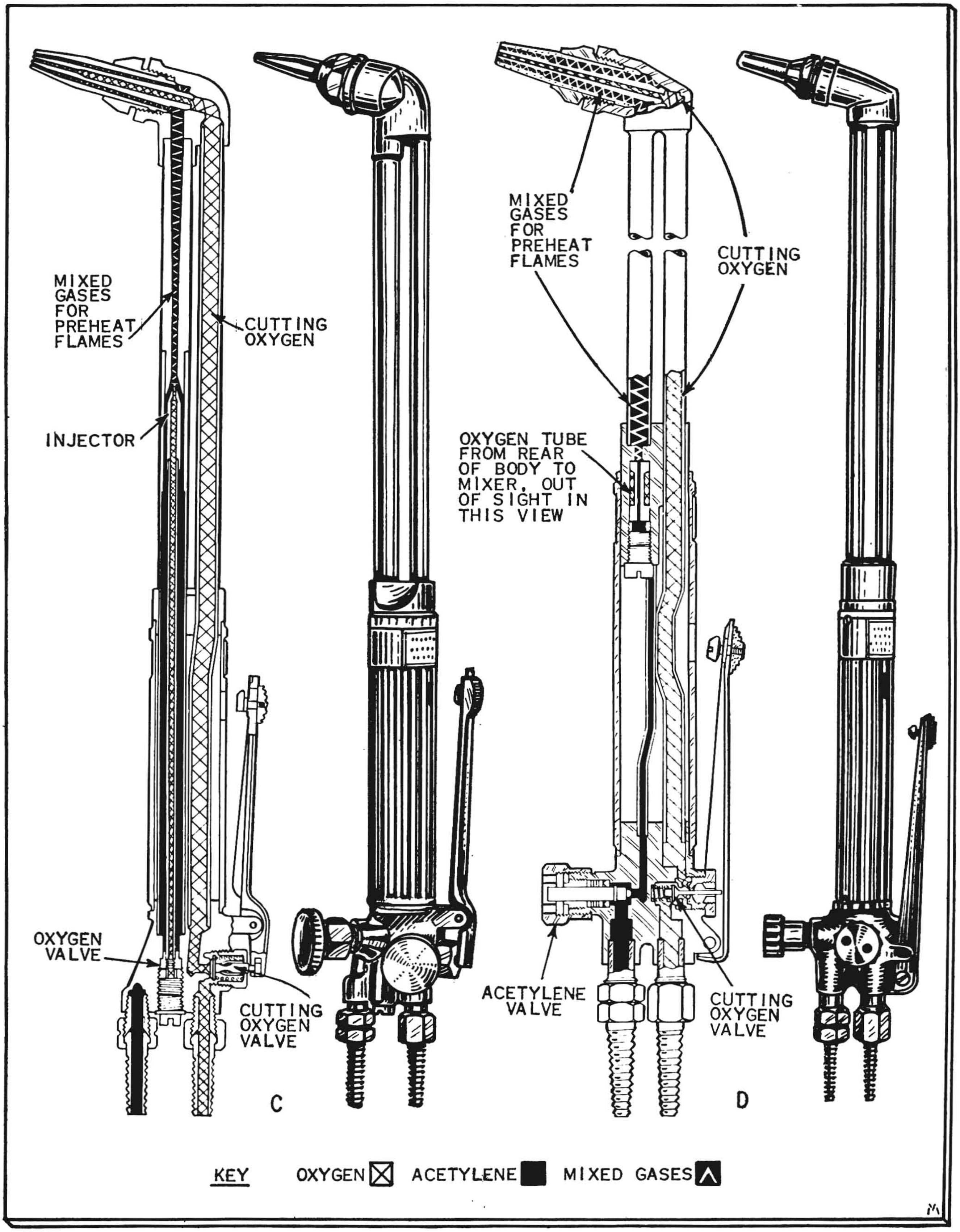

Figure 6. (C) A typical injector-type cutting blowpipe. (D) A typical medium-pressure-type cutting blowpipe.