OXYACETYLENE WELDING AND CUTTING INSTRUCTION COURSE

(LECTURES)

AIR REDUCTION
NEW YORK 17, N. Y.

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Price $1.00

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OFFICES IN PRINCIPAL CITIES IN THE UNITED STATES OF AMERICA

FOREWORD

Proficiency in the art of oxyacetylene welding and cutting can only be attained by intelligent application and constant practice on the part of the student. The principles involved in manipulating the oxyacetylene flame, in the welding and cutting processes, are relatively simple and easily demonstrated. Practice and more practice is the only means of obtaining the required skill.

An intelligent application of the welding and cutting arts, which marks the master welder from the ordinary welder, requires an understanding of the tools and materials handled and the past and present applications of these processes. No student of the oxyacetylene processes can be considered equipped for his work, without some knowledge of the history of his art, the properties of the materials he uses and the practical applications of his profession in industry.

For the purpose of broadening the horizon of the student of the oxyacetylene processes and insuring an intelligent application of the manipulative skill he is attaining, this series of lectures has been prepared. They are intended to furnish the instructor with material supplementing the companion book "Oxyacetylene Welding Instruction Course" (Exercises) which covers the physical phases of instruction in oxyacetylene welding and cutting.

AIR REDUCTION

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LECTURE No. 1

HISTORY AND PRINCIPLES OF OXYACETYLENE WELDING AND CUTTING PROCESSES

Fouché, Picard and LeChatelier — Calcium Carbide — Acetylene — Low Pressure and Medium Pressure Systems — The Oxyacetylene Welding Torch — Pressure Regulation — Oxygen and Acetylene Hose and Connections — Oxyacetylene Welding — Oxyacetylene Cutting — Oxygen Supply — Acetylene Supply.

Oxyacetylene welding and cutting have been brought to their present state of development within the present century. The oxyacetylene torch is accredited to two Frenchmen, Fouché and Picard, who made the first commercial torch in Paris in the year 1900. In 1895 LeChatelier, in a paper read before the Academie des Sciences on the temperatures of flames, stated that acetylene, burned with an equal quantity of oxygen, produces a temperature 1000° C. higher than the oxyhydrogen flame. The products of the primary combustion are carbon monoxide and hydrogen, which are reducing agents. This double property makes the use of acetylene of very great value for the production of high temperatures. Theoretically, it requires 2½ volumes of oxygen to completely burn 1 volume of acetylene, and this is actually what occurs, taking into account the oxygen taken from the air during the last phase of the combustion. The oxyacetylene flame has a temperature estimated to be approximately 6300° F. This temperature exceeds that of any other known flame.

CALCIUM CARBIDE: The discovery of a commercial method of producing calcium carbide, necessary for the commercial production of acetylene, dates back to 1892, when Thomas L. Willson, making experiments at Spray, N. C., to develop a commercial method of producing metallic calcium, using a Heroult electric furnace, succeeded, instead, in producing calcium carbide. Calcium carbide combines with water to form acetylene gas, leaving a residue of slaked lime. Acetylene had been known to science for many years, but no commercial method of producing it had ever been developed. The electric furnace, which produces calcium carbide from limestone and coke, provides a commercial source of this valuable gas.

ACETYLENE: The peculiar value of acetylene over other combustible gases lies in the fact that it is an endothermic compound. An endothermic compound is one that takes in or absorbs heat when produced and, consequently, liberates this heat when decomposed. Thus, when carbide is produced at the high temperature of the electric furnace, it absorbs heat which is stored in the calcium carbide formed. The acetylene gas made from the calcium carbide consists of a chemical union of two atoms of carbon and two atoms of hydrogen. It contains this endothermic heat in the form of potential energy. When the carbon and hydrogen atoms are again separated during combustion, this heat is released.

In burning acetylene, therefore, not only the heat from the union of carbon and hydrogen with oxygen is obtained but, in addition, heat is developed by the decomposition of the acetylene. The combustion of one cubic foot of acetylene produces approximately 1433 B.T.U.'s. Of these, some 228 B.T.U.'s, or 15.9%, are due to the heat of dissociation, or endothermic heat, of the acetylene. This disengages suddenly at the moment of decomposition and explains the very high temperature at the inner cone of the flame.

The highly incandescent bulb or inner cone of the oxyacetylene flame burning at the end of the torch tip is an evidence of its exceedingly high temperature, which surpasses that of any other known gas flame. It is this incandescent flame that is most useful in welding metals.

LOW PRESSURE AND MEDIUM PRESSURE SYSTEMS: The first oxyacetylene torch was invented by Edmond Fouché, who at the time was General Manager of the Compagnie Francaise de l'Acetylene Dissous. It was a high-pressure torch, because, at that time, acetylene was compressed in acetone cylinders under several atmospheres pressure. It was quite easy to obtain a good mixture from both gases entering the torch under many pounds pressure. Some time later Fouché devised a low-pressure torch which used acetylene from low-pressure generators. This torch received its oxygen under high pressure, which, on entering the chamber in the torch, expanded and drew acetylene from the acetylene orifice by the injector principle. These were the pioneer torches.

The high-pressure torch mixed the gases at the "haft" and they passed the entire length of the torch in the mixed state. This was necessary to obtain a perfect mixture under high-pressure. But, if at any time the velocity of the mixed gases in the torch nozzle was less than the velocity of the flame, there was a backfire, and the entire torch would quickly burn unless turned off at once. Backfires occurred when the tip was held too close to the work. On the other hand, the low-pressure torch was apt to send an excess of oxygen into the flame which resulted in a burned weld. This torch was also subject to frequent backfires. The firm of A. Boas-Rodrigues & Compagnie of Paris later

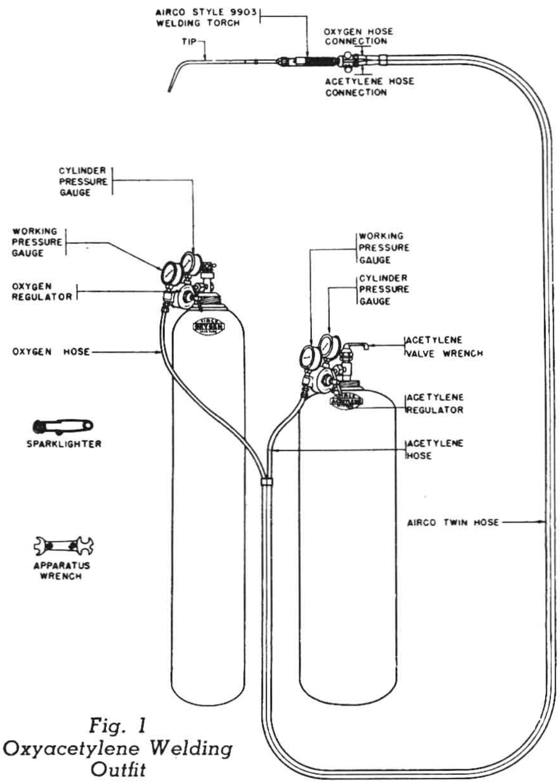

Fig. 1
Oxyacetylene Welding Outfit

devised a medium-pressure torch in which oxygen was used at high pressure and acetylene at about 3 psi. pressure. This allowed the mixing to be done close to the nozzle.

Meanwhile the Gauthier-Ely so-called "medium-pressure system" had been developed, and later the rights for this superior system were secured for the United States and Canada by Messrs. Davis and Bournonville, who, in January, 1907, organized the Davis-Bournonville Company. This company was consolidated with the Air Reduction Company in 1922. **1**

The medium-pressure torch system, as it is now known, employs acetylene under pressure of 1 to 15 psi. and oxygen under approximately the same pressure. The pressures employed depend on the size of the tip in use. Thus, medium-pressure torches are supplied with acetylene under higher pressure than in the low-pressure torches. If the acetylene used in these medium-pressure torches is supplied directly from acetylene generators, they must also be of the pressure type. The medium-pressure system has several inherent advantages in the operation of torches, acetylene generators, and gas distributing systems.

Both oxygen and acetylene pressures are motive forces in the medium-pressure torch, and this condition is favorable to the ideal mixture of gases which is necessary for the best results in welding. The ideal condition in a welding torch is realized when the volume of acetylene burned at the tip is exactly equal to the volume of oxygen passing through the torch. This condition is readily obtained with medium pressure equipment.

THE OXYACETYLENE WELDING TORCH: The oxyacetylene torch is a tool for combining oxygen and acetylene in nearly equal volumes, mixing the gases and burning them at the end of a tip. The torch is fitted with interchangeable tips, which enable the operator to adapt the size of the flame to the thickness of the metal to be welded. The welding torch has two tubes (one for oxygen and one for acetylene), also a mixing chamber, and handle and needle valves for control and adjustment of the flame. A welding outfit consists of a torch, lengths of hose to connect the torch to the sources of gas supply, pressure regulators or reducing valves, and cylinders containing oxygen and acetylene under pressure.

In many large plants the oxygen and acetylene cylinders are manifolded and the gases piped to the welding stations. Acetylene is also generated directly from calcium carbide in the larger plants, the gas being distributed through pipe lines to welding and cutting stations. When the gases are distributed through pipe lines, the welding and cutting stations are provided with pressure regulators on both the oxygen and acetylene outlets to

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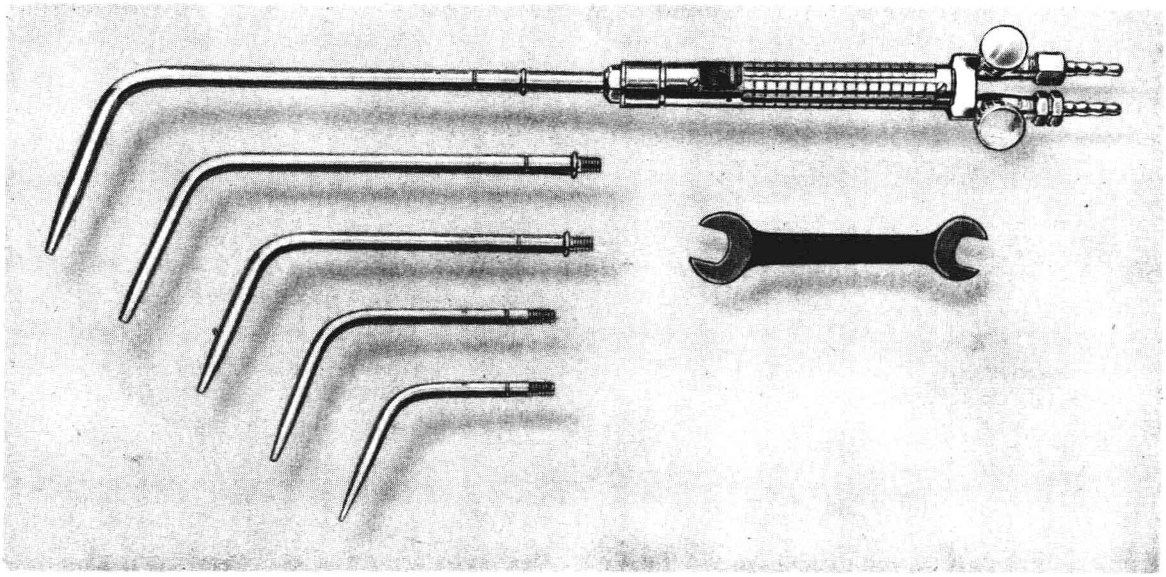


Fig. 2. Airco Style 9803 Welding Torch

regulate the pressures to meet the individual operator's requirements. The advantage of a piping system is that the operator does not have to handle the gas cylinders.

PRESSURE REGULATORS: Oxygen and acetylene compressed in cylinders are under pressures much too high for direct use in welding and cutting. Consequently, the gas pressures must be reduced and regulated by the pressure reducer or pressure regulator. A typical pressure regulator consists of a strong forged bronze case, a gas nozzle, a valve, a compensating spring, a diaphragm, a diaphragm adjusting spring, an adjusting screw, a cylinder pressure gauge, a working pressure gauge, a filter and a safety valve. The flow of high-pressure gas from the cylinder into the regulator is restrained at the end of the nozzle by a valve seat which is held against the nozzle opening by the compensating spring. The valve seat is flexibly connected to the diaphragm by means of a stirrup, and the compensating spring reacts on the diaphragm and thence on the valve seat.

Pressure on the diaphragm necessary to open the valve is exerted by the operator by means of the adjusting screw which compresses the adjusting spring. When the adjusting screw is released (unscrewed) the valve, under pressure of the compensating spring, shuts off the gas flow. Compression of the adjusting spring with the adjusting screw forces the valve seat away from the nozzle, and permits the gases to escape into the so-called low-pressure chamber beneath the diaphragm. The gas pressure underneath the diaphragm tends to push it up, compress the adjusting spring and close the valve. When the pressure builds up in the low-pressure chamber to the point where it overcomes the adjusting spring pressure, the valve seat closes tightly and no more gas is admitted until the pressure beneath falls off. Thus the regulator automatically supplies gas at a predetermined working pressure.

The high-pressure gauge on the regulator connected to the high-pressure inlet indicates the gas pressure in the cylinder. The low-pressure gauge attached to the regulator connects with the low-pressure chamber and indicates the working pressure. The operator depends upon the pressure gauges to indicate the gas pressures in the cylinders and the working pressure used for the operation of the torch. The working pressure should be adjusted to suit the size of the tip in use, as indicated by the tables furnished by the torch manufacturers. This is important. Troubles experienced by oxyacetylene welders often are due to the use of the wrong size tip or the adjustment of the oxygen and acetylene pressures to other than the respective pressures specified by the manufacturers.

A safety relief valve, which automatically relieves excessive pressure, prevents the pressure in the low-pressure chamber from building-up to a dangerous point. The gas coming from the cylinders is filtered through a filter assembly which contains a screen and glass wool.

OXYGEN AND ACETYLENE HOSE AND CONNECTIONS: The hose used for welding and cutting is specially manufactured for this service. It must be of ample strength to resist internal pressure, sufficiently flexible to yield readily to torch movements, and absolutely non-porous. The oxygen

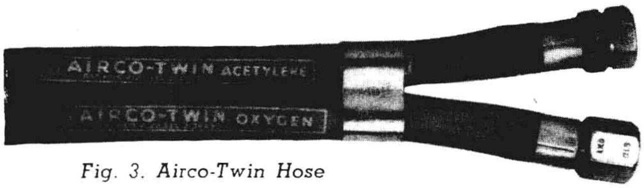


Fig. 3. Airco-Twin Hose

hose is **black**, and is fitted with connections and swivel nuts to attach to the oxygen regulator and oxygen needle valve on the torch. The acetylene hose is red and is fitted with connections that can only be attached to the acetylene regulator and acetylene needle valve on the torch. Standard hose length for station welding is 12½ feet. Single hose is furnished in sizes from ⅛ to ½ in. Airco-Twin hose consisting of two lines molded together, side by side, into a single light and flexible unit, is the most popular at present.

OXYACETYLENE WELDING: Welding with the oxyacetylene torch is the process of joining two metallic objects by fusing or melting their adjacent edges, thus forming a pool of molten metal, which, on cooling, forms a solid bond between them. Filler metal generally is added to build up the weld and to reinforce it. The filler metal is melted from the end of a wire known as the welding rod.

The usual principle followed in welding metals is to use welding rod of approximately the same chemical composition as the metal welded. Thus, low-carbon steel is generally welded with low-carbon rod, cast iron with cast iron rod, copper with copper wire, aluminum with aluminum rod, and so on. However, this principle does not always apply.

1

OXYACETYLENE CUTTING: The principle of torch cutting is based upon the combustibility of steel when heated to a bright red and brought in contact with high-purity oxygen (under pressure). Although resembling the welding torch in some respects, the cutting torch is a different tool, its function being to separate instead of to unite. It has an additional tube for high-pressure oxygen, and the cutting tip is made with a number of holes. Through the center orifice passes a stream of high purity oxygen which can be directed against the steel to be cut, while the holes surrounding the center orifice pass mixed oxygen and acetylene for the preheating flames. The heat necessary for starting and maintaining combustion is supplied by these preheating flames surrounding the cutting jet.

The cutting torch is furnished with interchangeable tips for cutting steel from ¼-inch or thinner to 12 inches or more in thickness. Oxyacetylene cutting is applied principally to steel, wrought iron, cast iron and other ferrous metals. The first cutting torches were welding torches to which a third tube was added, connected by a separate hose to an oxygen supply. Later developments eliminated the third hose and pressure regulator, and made it possible to use one oxygen supply, for both preheating and cutting.

OXYGEN SUPPLY: Oxygen for welding and cutting was at first produced by various chemical processes, all costly and unsatisfactory, and later by air liquefaction and water electrolysis. The air liquefaction process is employed almost exclusively today. It is now possible, by improved methods, to produce oxygen from the air of 99.5 per cent purity. Oxygen is supplied in two sizes of steel cylinders containing **244** or **122** cu. ft. under **2200** psi. pressure.

ACETYLENE SUPPLY: Acetylene is supplied for welding and cutting in Airco No. 5 cylinders, containing about **260** cu. ft. of gas, or in the No. 4 size cylinders containing about 116 cu. ft., both at 250 psi. pressure.

LECTURE No. 2

SAFETY PRECAUTIONS AND OPERATING INSTRUCTIONS FOR OXYACETYLENE EQUIPMENT

Oxyacetylene Hazards — Oxygen and Oxygen Cylinders — Acetylene and Acetylene Cylinders — Combustible Gas Leak Dangers — Welders' Dress — Eye Protection — Setting-Up, Turning On Gases, Lighting Torch and Shutting-Down — Safety Rules.

Certain dangers and hazards are inherent or incidental to every trade, industry and profession. A paper-hanger breaks his neck falling from a stepladder, a carpenter cuts off a finger with a hatchet, or a machinist skins his knuckles when a wrench slips and dies of blood poisoning because he neglects the wound. It is difficult, if not impossible, to separate the inherent hazards from the incidental ones. The paper-hanger might fall from a stepladder while trimming a tree in his backyard with like results. Thus the *majority of accidents are the result of carelessness or disregard of the fundamental principles of safe conduct.*

OXYACETYLENE HAZARDS: The use of oxyacetylene equipment involves hazards which are specific to such equipment and others which relate to heating apparatus in general. The oxyacetylene flame and the sparks produced in cutting will ignite combustible materials and may cause damaging fires. The precautions commonly observed to prevent fire, when handling blow-torches and other open flames, should always be observed in handling oxyacetylene equipment.

The specific hazards of the oxyacetylene process relate to the gases—oxygen and acetylene—their containers, and the apparatus used to control and combine them into a flame.

OXYGEN AND OXYGEN CYLINDERS: Oxygen is the active element in combustion. When commercially pure, it is capable of producing combustion effects never experienced with air alone. For example, a drop of oil on an oxygen regulator may take fire "spontaneously" and develop sufficient heat to cause an explosion, the effect of which may be serious.

Commercial considerations require that oxygen be highly compressed in the cylinder to a pressure of 2200 psi. It is obvious that cylinders filled to 2200 psi. with gas that actively supports combustion should be handled carefully. They should not be banged one against another or dropped. They should not be exposed to furnace heat nor allowed to stand where oil or grease will drip on them.

Certain combustible materials must be used in constructing pressure regulators and hose. Rubber hose though it burns slowly in air, burns rapidly, or with explosive violence when filled with oxygen. Hence, care must be taken to prevent fire starting in oxygen regulators and hose.

ACETYLENE AND ACETYLENE CYLINDERS: Acetylene supplied in cylinders is under initial pressure of about 250 psi. The steel cylinder is closely packed with a porous material or filler, and the filler is soaked with acetone. The acetylene is then dissolved under pressure in the acetone. This combination of a porous filler soaked with acetone provides for safe transport of a gas that cannot be safely compressed in the free state to more than 15 psi. In the dissolved state, however, it is safely compressed to 250 psi. If acetylene cylinders are roughly handled, dented or allowed to fall, the porous filler may be displaced or compressed, creating a hazardous condition. Acetylene cylinders should never be exposed to furnace heat.

COMBUSTIBLE GAS LEAK DANGERS: Any combustible gas—city gas, hydrogen, propane or acetylene—leaking into a closed space creates a dangerous condition. An open light or spark may cause an explosion. Hence, it is of great importance to prevent leaks from acetylene regulators, hose and hose connections, and to keep the hose in good condition. Always close acetylene cylinder valves when empty to prevent escape of residual acetylene.

WELDERS' DRESS: Clothing and suitable protection for the eyes, hands and feet are important safety measures in oxyacetylene welding and cutting. One-piece overalls closely fitted at the neck and wrists are recommended. They should be free of holes. A ragged suit invites fires and burns.

High shoes with tongues, laced to the top, should be worn and the overalls should cover the uppers. Low or damaged shoes are a hazard because of the possibility of sparks and drops of molten metal falling into the holes and burning the feet.

Gloves with gauntlets are necessary to protect the hands and wrists from the heat. Cotton gloves should be avoided unless fireproofed. Untreated cotton is very likely to take fire and cause burns. Horsehide leather gloves give uniform satisfaction, being long wearing and resistant to fire.

EYE PROTECTION: Goggles with colored lenses suited to the eyes are required for eye protection.

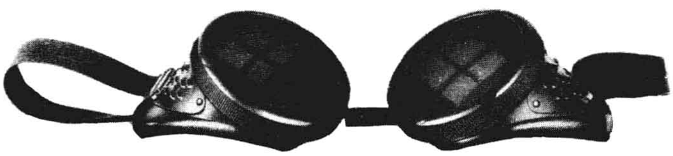


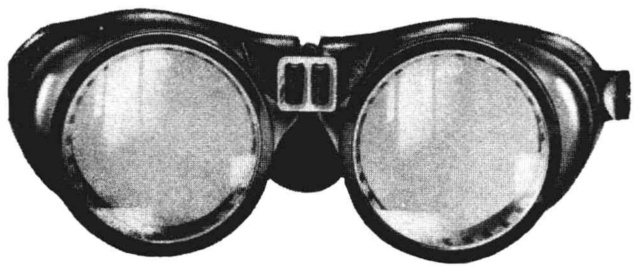
Fig. 4. Airco Goggles For Welders and Cutters

This protection is necessary not only because of the injurious effects of the infra-red and ultra-violet rays, but also because of flying sparks and globules of molten metal. Eye protection is highly important and it involves much more than can be covered here in detail.

Goggles should be individually fitted to secure best efficiency and personal comfort. When fitting colored lenses, the rule should be to use no darker shade than necessary for eye protection and eye comfort. If the lenses are too dark the welder will be unable to see clearly what he is doing, and if too light, he is likely to suffer from light and heat effects. As a rule, men with blue eyes require darker lenses than men with brown eyes.

For sanitary reasons goggles should not be exchanged. **2**

A simple test of the suitability of colored lenses may be made by using a pair of goggles fitted with them while welding and then removing the goggles and noting whether white spots dance before the eyes. If white spots appear, the lenses do not afford sufficient protection and darker ones should be



COVERSPECS GOGGLES

Fig 4a. For Welders and Cutters who wear Eyeglasses

provided. If the wearer is unable to see the welding puddle clearly and distinguish a neutral flame from a carburizing or an oxidizing flame, the lenses are too dark. The goggles should be properly ventilated. When selecting goggles, get only the best.

A few words in regard to the use of spectacles with colored lenses. Spectacles are used only when welding and cutting light materials. They should

Fig. 5. Airco Spectacles With Noviweld Lenses

never be used when welding or cutting heavier materials or when there is danger from flying sparks.

2 **SETTING UP, TURNING ON GASES, LIGHTING THE TORCH AND SHUTTING DOWN:** Safe habits in handling oxyacetylene welding and cutting equipment are just as important to an operator as his manipulative skill. Therefore, connecting the pressure regulators to the cylinders and hose, connecting the hose to the torch, turning on the gases and lighting the torch are operations that should be performed systematically in a definite order to avoid mistakes.

By establishing and following a regular system, opportunities for neglecting a connection or valve will be minimized and safe operating conditions promoted. Remember it always seems to be the connections you are sure you tightened, which leak at an inopportune moment. The following instructions for setting up portable Airco welding and cutting apparatus, turning on the gases and lighting the torch are based on years of experience, and assure practical safety to the operator and the apparatus.

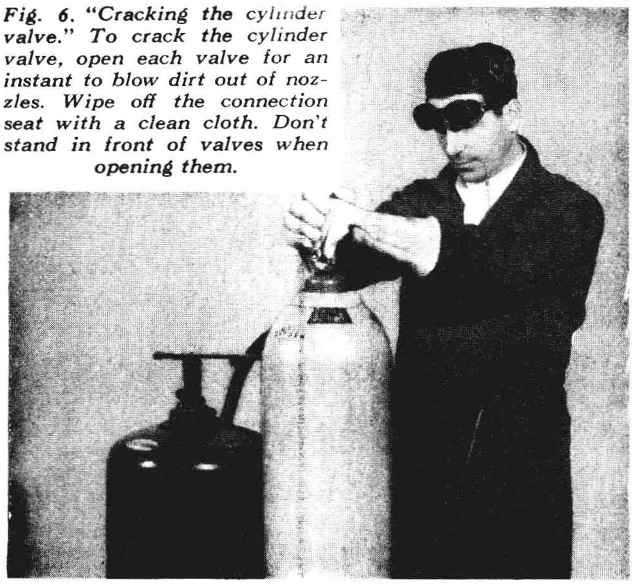


Fig. 6. "Cracking the cylinder valve." To crack the cylinder valve, open each valve for an instant to blow dirt out of nozzles. Wipe off the connection seat with a clean cloth. Don't stand in front of valves when opening them.

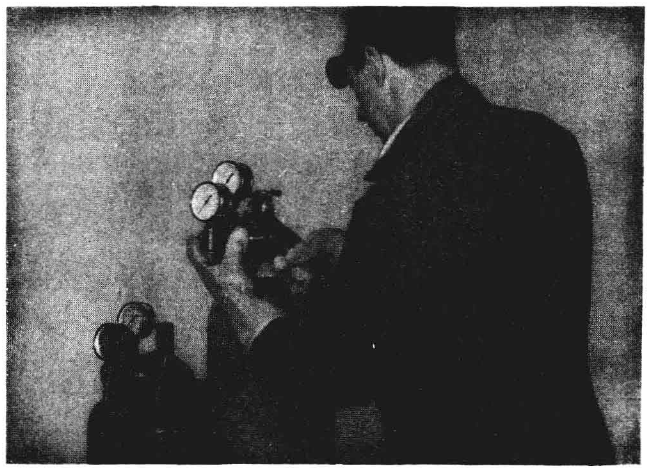


Fig. 7. Attaching the pressure regulators. To attach the regulators, connect the acetylene regulator to the acetylene cylinder and the oxygen regulator to the oxygen cylinder. Screw the nuts up tightly with a close-fitting wrench.

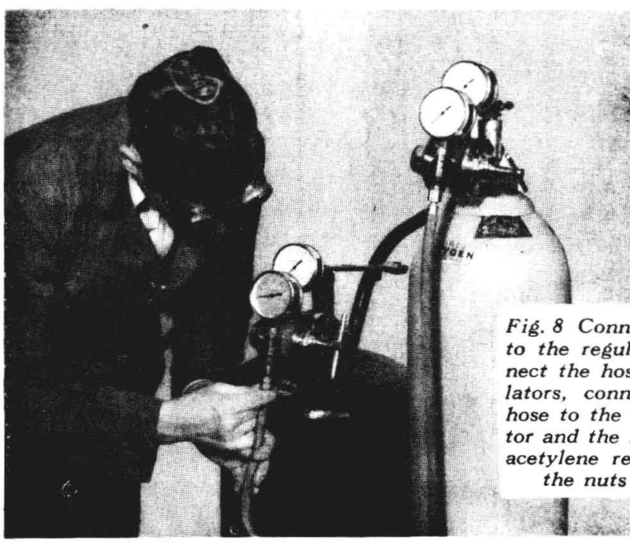


Fig. 8 Connecting the hose to the regulators. To connect the hose to the regulators, connect the green hose to the oxygen regulator and the red hose to the acetylene regulator. Screw the nuts up tightly.

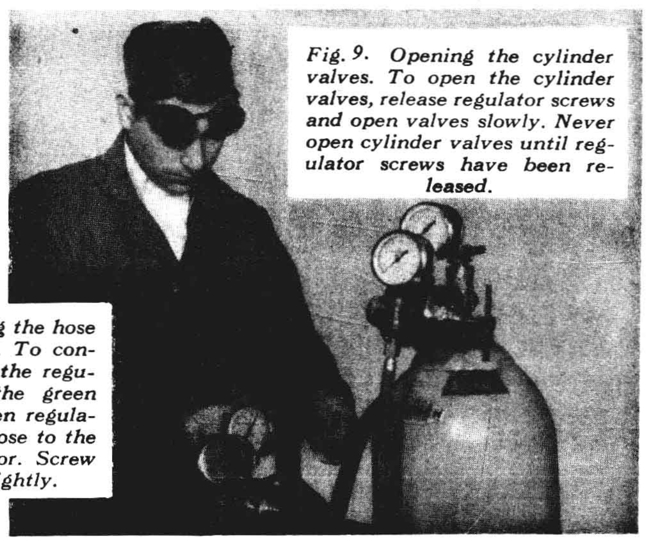


Fig. 9. Opening the cylinder valves. To open the cylinder valves, release regulator screws and open valves slowly. Never open cylinder valves until regulator screws have been released.

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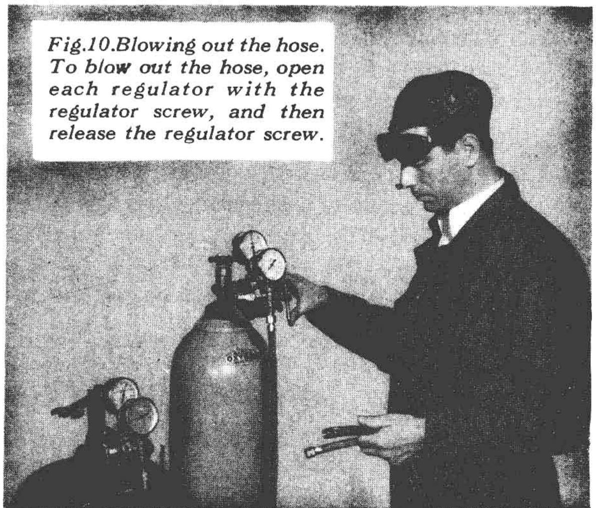

Fig. 10. Blowing out the hose. To blow out the hose, open each regulator with the regulator screw, and then release the regulator screw.

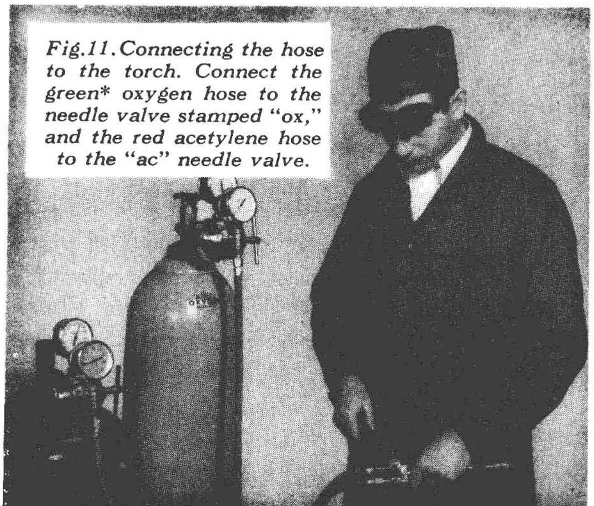

Fig. 11. Connecting the hose to the torch. Connect the green oxygen hose to the needle valve stamped "ox," and the red acetylene hose to the "ac" needle valve.*

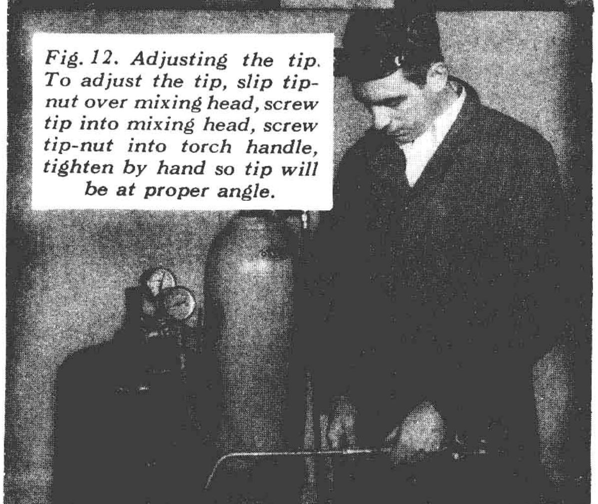

Fig. 12. Adjusting the tip. To adjust the tip, slip tip-nut over mixing head, screw tip into mixing head, screw tip-nut into torch handle, tighten by hand so tip will be at proper angle.

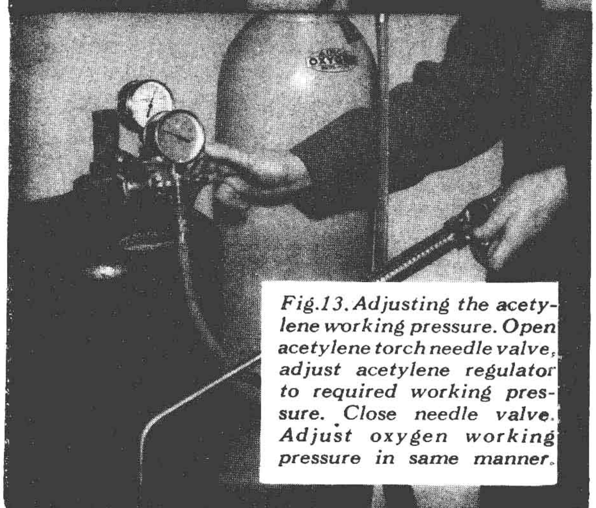

Fig. 13. Adjusting the acetylene working pressure. Open acetylene torch needle valve, adjust acetylene regulator to required working pressure. Close needle valve. Adjust oxygen working pressure in same manner.

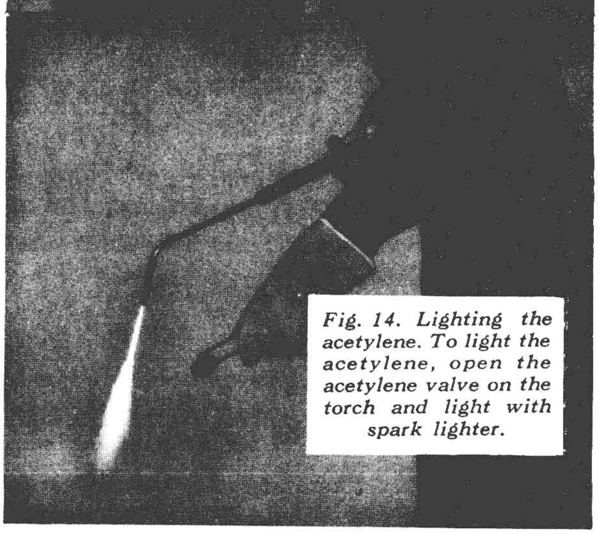

Fig. 14. Lighting the acetylene. To light the acetylene, open the acetylene valve on the torch and light with spark lighter.

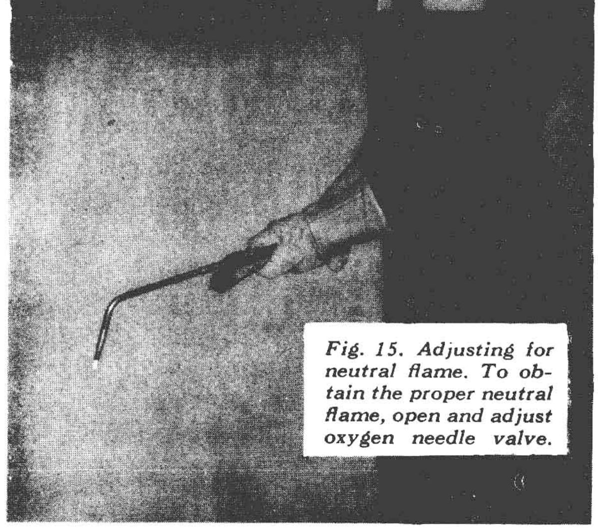

Fig. 15. Adjusting for neutral flame. To obtain the proper neutral flame, open and adjust oxygen needle valve.

*Due to the war, oxygen hose is also supplied in black.

FLAME ADJUSTMENT

2 To assist in correct understanding of the possible flame adjustments refer to the "Frontispiece". This illustrates, by means of natural color photographs, the actual flame conditions as seen without goggles.

The flame pictured at the top is acetylene only, burning in air. It is the flame secured when the torch is first lighted. Insofar as welding and cutting are concerned it has no practical application.

The next flame shown represents the condition obtained as the oxygen needle valve is gradually opened. The long streamer (incandescent carbon particles from the excess acetylene) is shortened by the admission of more oxygen. This flame adjustment has very limited use. With a moderately long streamer it may be used for silver brazing operations.

The third flame adjustment illustrated is in reality the same basic condition as the second flame with this difference — more oxygen has been admitted to the flame in third position. This flame when adjusted to give a streamer 25% - 50% longer than the length of the inner cone, is used for Aircowelding. This flame adjustment is also recommended for use with the alloy steel gas welding rods such as Airco No. 1 and Airco No. 4.

The neutral flame, fourth from the top, is the one most commonly employed in welding steel, aluminum, etc. When in doubt as to the correct flame to use always select a neutral flame as there is less possibility of injury to the molten metal.

The last flame shown demonstrates the oxidizing condition. This flame must never be used for welding steel, aluminum etc. Its use is limited to the welding of copper and certain copper base alloys.

TABLE I
APPROXIMATE GAS PRESSURES FOR WELDING
WITH WELDING TORCHES STYLES 9803 AND 9903

Tip No.	0	1	2	3	4	5	6	7	8	9	10	11	12
Mixer	00–1	1–7	1–7	1–7	1–7	1–7	1–7	6–10	6–10	6–10	10–12	10–12	10–12
Thickness of Metal (In.)	1/32	1/16	⅛	¼	⅜	½	⅝	¾	1	1½	2 up	2 up	Extra Heavy
Oxygen Pressure (psi.)	1	1	2	3	4	5	6	5	6	8	8	10	12
Acetylene Pressure (psi.)	1	1	2	3	4	5	6	5	6	8	8	10	12

TABLE II
APPROXIMATE GAS PRESSURES FOR CUTTING
WITH CUTTING TORCHES STYLES 9000, 3000, 1100, 9975—STYLE 144 TIPS

Thickness of Metal (In.)	¼	⅜	½	¾	1	1½	2	3	4	5	6	8
Airco Cutting Tip Size	0	1	1	2	2	3	4	5	5	6	6	7
Oxygen Pressure (psi.)	30	30	40	40	50	50	50	50	60	50	55	60
Acetylene Pressure (psi.)	3	3	3	3	3	3	3	4	4	5	5	6
Cleaning Drill Size For Cutting Jet	63	57	57	55	55	53	50	46	46	42	42	35

CAUTION: Never start welding or cutting with apparatus connected to an acetylene pipe line without making sure that the generator is operating or in operating condition.

TAKING DOWN EQUIPMENT:

1. Close acetylene valve on torch first.
2. Close oxygen valve on torch.
3. Close acetylene cylinder valve.
4. Close oxygen cylinder valve.
5. Open torch acetylene valve, with oxygen valve closed, to drain the line; release the adjusting screw on the acetylene regulator, then promptly close torch acetylene valve.
6. Open torch oxygen valve, with acetylene valve closed, to drain the line; release the adjusting screw of the oxygen regulator, then promptly close torch oxygen valve.
7. Flashbacks result from mixed gases in either oxygen or acetylene hose. By following these rules acetylene will not get over into the oxygen line nor oxygen into the acetylene line when starting or shutting down. If torch flame is properly adjusted and maintained, with the correct pressures, and tip outlets kept free from obstruction, flashbacks will be eliminated.
8. Remove regulators from cylinders when moving cylinders. Replace caps over cylinder valves when cylinders are empty, and mark cylinder "MT."

SAFETY RULES

OXYGEN:

1. Always refer to oxygen by its full name "oxygen" and not by the word "air."
2. Never permit oil or grease to come in contact with oxygen cylinders—valves—regulators—hose or fittings. Do not handle oxygen cylinders or apparatus with oily hands or gloves.
3. Never use regulators, hose or other pieces of apparatus that have been used for any other gases.
4. Open oxygen cylinder valve fully when in use.
5. Never attempt to mix any other gases in an oxygen cylinder.
6. Never use oxygen near inflammable materials, especially oil, grease or any substance likely to cause or accelerate fire. Oxygen itself is not inflammable but does support combustion.
7. Do not store oxygen and acetylene cylinders together. They should be separately grouped.

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ACETYLENE:

1. Call acetylene by its full name "acetylene" and not by the word "gas." Acetylene is far different from city or furnace gas.
2. Acetylene cylinders should be used and stored in an upright position.
3. Keep sparks, flames and heat away from acetylene cylinders.
4. Never use acetylene from cylinders without reducing the pressure through a suitable regulator attached to the cylinder valve.
5. Turn the acetylene cylinder so that the valve outlet will point away from the oxygen cylinder.
6. When opening an acetylene cylinder, turn key one-half turn only.
7. Never interchange acetylene regulators, hose or other apparatus with similar equipment intended for oxygen.
8. Never attempt to transfer acetylene from one cylinder to another nor to refill an acetylene cylinder, nor to mix any other gas or gases in an acetylene cylinder.
9. Keep acetylene cylinder key for opening cylinder valve on valve stem while cylinder is in use.
10. When returning empty cylinders see that valves are closed tight to prevent escape of residual acetylene.
11. Never test for acetylene leaks with an open flame; use soapy water.
12. Should a leak occur in an acetylene cylinder, take cylinder out in the open air, keeping well away from fires or open lights. Notify the manufacturer at once.

LECTURE No. 3

OXYGEN, OXYGEN CYLINDERS AND USES

Combustion — Historical — Properties — Manufacture — Commercial Uses — Oxygen in Cylinders — Effect of Oxygen Purity in Cutting — The Oxygen Lance — Miscellaneous Uses.

Oxygen is the life-and-fire-sustaining element of the air. Remove the oxygen and all normal animal life quickly dies—fires no longer burn. About one-fifth of the earth's atmosphere is oxygen and nearly four-fifths nitrogen.

TABLE III
ANALYSIS OF ATMOSPHERIC AIR:

Gas	*Per Cent, by Volume*
Nitrogen	78.03
Oxygen	20.99
Argon	0.94
Carbon Dioxide	0.034
Hydrogen	0.01
Neon	0.0066
Helium	0.0002
Krypton	0.00001
Xenon	0.0000011

The proportions of the atmospheric gases at or near sea level are practically the same wherever an air sample is taken except in the vicinity of large cities where slightly more carbon dioxide and other gaseous products of combustion are found.

COMBUSTION: Oxygen is "consumed" in fire, that is, it enters into various chemical combinations with the combustible elements in the fuel and produces heat. Air containing oxygen is necessary for combustion. Shut off the air supply and a fire quickly dies. Blow into a fire and it burns more brightly because more oxygen is forced through the fuel. Remove all other gaseous elements in the air, leaving the pure oxygen, and the intensity of combustion is greatly increased. The purer the oxygen the hotter the fire and the less the heat lost with the products of combustion. All substances which burn in air, burn with much greater brilliancy in pure oxygen, and many that cannot be burned in air at all can be burned quite easily in oxygen. Thus, an iron wire, if previously heated to the ignition temperature—about 1600° F.—burns with dazzling brilliancy in oxygen. The temperature of a gas flame burning in oxygen is very much higher than that of the same gas burning in air.

HISTORICAL: Oxygen was recognized by its properties as far back as the eighth century among the Chinese who knew that the "active" component of the air combined with some metals, with sulphur and with charcoal and that this active component could be obtained pure from saltpeter and certain other minerals. Priestley is generally considered to have discovered oxygen in 1777. The name oxygen (meaning acid-forming) was given to the gas by Lavoisier who at that time thought it was an essential constituent of all acids.

PROPERTIES: Oxygen is a colorless, tasteless and odorless gas. It is 1.1056 times as heavy as air; 12.07 cu. ft. at atmospheric pressure and 70° F. weigh one lb., and one cu. ft. weighs 0.08283 lbs.

Oxygen forms oxides by direct combustion with nearly all other elements, the exceptions being argon, bromine, chlorine, fluorine, gold, helium, iodine, neon, platinum and silver. Most of the non-metallic elements combine with oxygen to form acids; hydrogen forms a neutral oxide, water. A few of the metals in the molten state absorb oxygen which is given off again when the metal solidifies. When heated to 842° F., silver takes up about five times its volume of oxygen, gold about 35 to 40, platinum 65 to 75, and palladium about 500 times its volume.

Oxygen is non-inflammable but its combination with other elements or materials with evolution of heat and light is commonly known as combustion, and the material combining thus with oxygen is said to be inflammable.

MANUFACTURE: The following methods have at various times been used for the production of oxygen in quantity: 1. The ignition of niter. The oxygen from this source was contaminated with oxides of nitrogen. 2. Heating manganese dioxide. This was one of the cheapest of the early methods. 3. Heating potassium chlorate manganese dioxide mixture. Until about 1885 this was the almost exclusive source for the considerable quantities of oxygen used for limelight. 4. The alternate formation and decomposition of barium peroxide. 5. Electrolysis of water, producing both oxygen and hydrogen. 6. Fractional distillation of liquid air. Since the boiling point of oxygen at atmospheric pressure is 296.3° F. while that of nitrogen is 320.5° F., by proper fractionating apparatus the nitrogen in liquid air can be allowed to boil off first, leaving the oxygen behind. The liquid air method releases the vast store of atmospheric oxygen for commercial use at much lower cost than the other processes and is the one generally employed.

COMMERCIAL USES: Commercial oxygen is chiefly used for welding and cutting with oxyacetylene torches. With these torches, for the first time, the welding of all commercial metals, including wrought iron, steel, cast iron, aluminum, copper, brass, bronze, etc., was made possible.

The cutting torch uses much more oxygen in normal operation than a welding torch, and because of the many needs for quick and easy cutting of steel shapes much more oxygen is used in cutting than in welding. The oxygen cutting torch has made possible the salvage of heavy scrap at low cost depending on the facilities provided for handling and the general conditions as to thickness, paint, scale, etc. Many other uses for the cutting torch have been developed, particularly in the repair of locomotives and cars. Fabrication of steel for buildings, bridges, tanks, and machine parts has been revolutionized by the cutting torch.

Steel foundry practice has been greatly improved by cutting risers with oxygen. The risers are made larger and placed where they will insure sound castings irrespective of position. When the risers had to be cut with cold saws it was necessary to place them where the saw could operate, with the result that too often the metal was not fed into the mold correctly and defective castings were made.

OXYGEN IN CYLINDERS: The bulk of commercial oxygen is supplied to users in seamless steel cylinders containing 244 cu. ft. at a pressure of 2200 psi. at 70° F. The diameter of a standard cylinder is about 9 in. and the height from base to top of cap 54 in. The average weight of an oxygen cylinder is 133 lbs. empty, and 150 lbs. filled to the standard pressure of 2200 psi. at 70° F. A smaller commercial oxygen cylinder, containing 122 cu. ft. at 2200 psi. pressure and 70° F. is also furnished for the convenience of users requiring small volumes or for ease of handling on outside jobs.

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The pressure of oxygen in the cylinder varies with the temperature according to a definite rule, but the weight and the actual volume of oxygen at 70° F. remains, of course, unchanged. Thus, an oxygen cylinder brought into the shop from outside at zero weather will show pressure of only about 1630 psi. when the pressure regulator is first attached, but as the cylinder and contents warm up the pressure rises to about 2200 psi. at average shop temperature.

The volume remaining in an oxygen cylinder partly discharged can be read approximately on

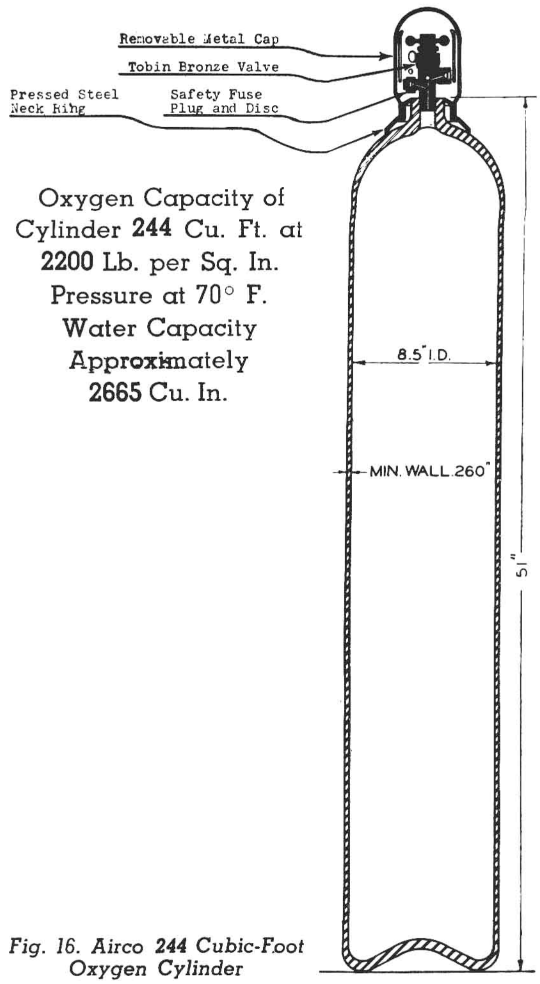

Fig. 16. Airco 244 Cubic-Foot Oxygen Cylinder

3 the regulator pressure gauge, inner graduated circle. The following table gives the volume content of a 244-cubic foot Airco cylinder indicated by gauge pressure:

Oxygen cylinders, in common with other cylinders containing gases under pressure transported by common carriers, are subject to the Interstate Commerce Commission Rules governing such packages. Oxygen cylinders are initially tested to 3360 psi. by the manufacturer and periodically thereafter by the oxygen producer. Damaged cylinders, that is, cylinders badly dented or corroded, must be taken out of service. The valve must be protected by a valve cap when shipped, whether filled or empty.

The valve stem is connected to the lower part or valve proper by a link. The link is purposely made weak so that it will break when overstrained without damaging the remainder of the valve. It is sufficiently strong to operate the valve in opening or closing under normal conditions, but it will break if a pipe wrench and undue pressure are used.

TABLE IV

VARIATIONS IN OXGYEN CYLINDER PRESSURES WITH TEMPERATURE CHANGES

Gauge pressures indicated for varying temperature conditions on a full cylinder initially charged to 2200 psi at 70°F. Values identical for 244 cu. ft. and 122 cu. ft. cylinder.

Temperature Degrees F.	Pressure psi. approx.	Temperature Degrees F.	Pressure psi. approx.
120	2500	30	1960
100	2380	20	1900
80	2260	10	1840
70	2200	0	1780
60	2140	—10	1720
50	2080	—20	1660
40	2020		

TABLE V

OXYGEN CYLINDER CONTENT

Indicated by Gauge Pressure

*at 70° F. **244** Cu. Ft. Cylinder*

Gauge Pressure psi.	Content Cu. Ft.	Gauge Pressure psi.	Content Cu. Ft.
190	20	1200	130
285	30	1285	140
380	40	1375	150
475	50	1465	160
565	60	1550	170
655	70	1640	180
745	80	1730	190
840	90	1820	200
930	100	1910	210
1020	110	2000	220
1110	120	**2090**	**230**
		2200	**244**

122-cu. ft. cylinder content one-half above volumes.