WELDING MATERIALS & INFORMATION

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***from the text of "OXY-ACETYLENE WELDING AND CUTTING, ELECTRIC AND THERMIT WELDING"**
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WELDING MATERIALS:--Production, Handling and Use of the Gases, Oxygen and Acetylene--Welding Rods--Fluxes--Supplies and Fixtures

OXY-ACETYLENE WELDING AND CUTTING MATERIALS

Welding._--Oxy-acetylene welding is an autogenous welding process, in which two parts of the same or different metals are joined by causing the edges to melt and unite while molten without the aid of hammering or compression. When cool, the parts form one piece of metal.

The oxy-acetylene flame is made by mixing oxygen and acetylene gases in a special welding torch or blowpipe, producing, when burned, a heat of 6,300 degrees, which is more than twice the melting temperature of the common metals. This flame, while being of intense heat, is of very small size.

Cutting._--The process of cutting metals with the flame produced from oxygen and acetylene depends on the fact that a jet of oxygen directed upon hot metal causes the metal itself to burn away with great rapidity, resulting in a narrow slot through the section cut. The action is so fast that metal is not injured on either side of the cut.

Carbon Removal._--This process depends on the fact that carbon will burn and almost completely vanish if the action is assisted with a supply of pure oxygen gas. After the combustion is started with any convenient flame, it continues as long as carbon remains in the path of the jet of oxygen.

Materials._--For the performance of the above operations we require the two gases, oxygen and acetylene, to produce the flames; rods of metal which may be added to the joints while molten in order to give the weld sufficient strength and proper form, and various chemical powders, called fluxes, which assist in the flow of metal and in doing away with many of the impurities and other objectionable features.

Instruments._--To control the combustion of the gases and add to the convenience of the operator a number of accessories are required.

The pressure of the gases in their usual containers is much too high for their proper use in the torch and we therefore need suitable valves which allow the gas to escape from the containers when wanted, and other specially designed valves which reduce the pressure. Hose, composed of rubber and fabric, together with suitable connections, is used to carry the gas to the torch.

The torches for welding and cutting form a class of highly developed instruments of the greatest accuracy in manufacture, and must be thoroughly understood by the welder. Tables, stands and special supports are provided for holding the work while being welded, and in order to handle the various metals and allow for their peculiarities while heated use is made of ovens and torches for preheating. The operator requires the protection of goggles, masks, gloves and appliances which prevent undue radiation of the heat.

Torch Practice._--The actual work of welding and cutting requires preliminary preparation in the form of heat treatment for the metals, including preheating, annealing and tempering. The surfaces to be joined must be properly prepared for the flame, and the operation of the torches for best results requires careful and correct regulation of the gases and the flame produced.

Finally, the different metals that are to be welded require special treatment for each one, depending on the physical and chemical characteristics of the material.

It will thus be seen that the apparently simple operations of welding and cutting require special materials, instruments and preparation on the part of the operator and it is a proved fact that failures, which have been attributed to the method, are really due to lack of these necessary qualifications.

OXYGEN

Oxygen, the gas which supports the rapid combustion of the acetylene in the torch flame, is one of the elements of the air. It is the cause and the active agent of all combustion that takes place in the atmosphere. Oxygen was first discovered as a separate gas in 1774, when it was produced by heating red oxide of mercury and was given its present name by the famous chemist, Lavoisier.

Oxygen is prepared in the laboratory by various methods, these including the heating of chloride of lime and peroxide of cobalt mixed in a retort, the heating of chlorate of potash, and the separation of water into its elements, hydrogen and oxygen, by the passage of an electric current. While the last process is used on a large scale in commercial work, the others are not practical for work other than that of an experimental or temporary nature.

This gas is a colorless, odorless, tasteless element. It is sixteen times as heavy as the gas hydrogen when measured by volume under the same temperature and pressure. Under all ordinary conditions oxygen remains in a gaseous form, although it turns to a liquid when compressed to 4,400 pounds to the square inch and at a temperature of 220° below zero.

Oxygen unites with almost every other element, this union often taking place with great heat and much light, producing flame. Steel and iron will burn rapidly when placed in this gas if the combustion is started with a flame of high heat playing on the metal. If the end of a wire is heated bright red and quickly plunged into a jar containing this gas, the wire will burn away with a dazzling light and be entirely consumed except for the molten drops that separate themselves. This property of oxygen is used in oxy-acetylene cutting of steel.

The combination of oxygen with other substances does not necessarily cause great heat, in fact the combination may be so slow and gradual that the change of temperature can not be noticed. An example of this slow combustion, or oxidation, is found in the conversion of iron into rust as the metal combines with the active gas. The respiration of human beings and animals is a form of slow combustion and is the source of animal heat. It is a general rule that the process of oxidation takes place withincreasing rapidity as the temperature of the body being acted upon rises. Iron and steel at a red heat oxidize rapidly with the formation of a scale and possible damage to the metal.

Air._--Atmospheric air is a mixture of oxygen and nitrogen with traces of carbonic acid gas and water vapor. Twenty-one per cent of the air, by volume, is oxygen and the remaining seventy-nine per cent is the inactive gas, nitrogen. But for the presence of the nitrogen, which deadens the action of the other gas, combustion would take place at a destructive
rate and be beyond human control in almost all cases. These two gases exist simply as a mixture to form the air and are not chemically combined. It is therefore a comparatively simple matter to separate them with the processes now available.

Water._--Water is a combination of oxygen and hydrogen, being composed of exactly two volumes of hydrogen to one volume of oxygen. If these two gases be separated from each other and then allowed to mix in these proportions they unite with explosive violence and form water. Water itself may be separated into the gases by any one of several means, one making use of a temperature of 2,200° to bring about this separation. The easiest way to separate water into its two parts is by the process called electrolysis (Figure 7). Water, with which has been mixed a small quantity of acid, is placed in a vat through the walls of which enter the platinum tipped ends of two electrical conductors, one positive and the other negative.

Tubes are placed directly above these wire terminals in the vat, one tube being over each electrode and separated from each other by some distance. With the passage of an electric current from one wire terminal to the other, bubbles of gas rise from each and pass into the tubes. The gas that comes from the negative terminal is hydrogen and that from the positive pole is oxygen, both gases being almost pure if the work is properly conducted. This method produces electrolytic oxygen and electrolytic hydrogen.

The Liquid Air Process._--While several of the foregoing methods of securing oxygen are successful as far as this result is concerned, they

are not profitable from a financial standpoint. A process for separating oxygen from the nitrogen in the air has been brought to a high state of perfection and is now supplying a major part of this gas for oxy-acetylene welding. It is known as the Linde process and the gas is distributed by the Linde Air
Products Company from its plants and warehouses located in the large cities of the country.

The air is first liquefied by compression, after which the gases are separated and the oxygen collected. The air is purified and then compressed by successive stages in powerful machines designed for this purpose until it reaches a pressure of about 3,000 pounds to the square inch. The large amount of heat produced is absorbed by special coolers during the process of compression. The highly compressed air is then dried and the temperature further reduced by other coolers.

The next point in the separation is that at which the air is introduced into an apparatus called an interchanger and is allowed to escape through a valve, causing it to turn to a liquid. This liquid air is sprayed onto plates and as it falls, the nitrogen return to its gaseous state and leaves the oxygen to run to the bottom of the container. This liquid oxygen is then allowed to return to a gas and is stored in large gasometers or tanks.

The oxygen gas is taken from the storage tanks and compressed to approximately 1,800 pounds to the square inch, under which pressure it is passed into steel cylinders and made ready for delivery to the customer. This oxygen is guaranteed to be ninety-seven per cent pure.

Another process, known as the Hildebrandt process, is coming into use in this country. It is a later process and is used in Germany to a much greater extent than the Linde process. The Superior Oxygen Co. has secured the American rights and has established several plants.

Oxygen Cylinders_.--Two sizes of cylinders are in use, one containing 100 cubic feet of gas when it is at atmospheric pressure and the other containing 250 cubic feet under similar conditions. The cylinders are made from one piece of steel and are without seams. These containers are tested at double the pressure of the gas contained to insure safety while handling.

One hundred cubic feet of oxygen weighs nearly nine pounds (8.921), and therefore the cylinders will weigh practically nine pounds more when full than after emptying, if of the 100 cubic feet size. The large cylinders weigh about eighteen and one-quarter pounds more when full than when empty, making approximately 212 pounds empty and 230 pounds full.

The following table gives the number of cubic feet of oxygen remaining in the cylinders according to various gauge pressures from an initial pressure of 1,800 pounds. The amounts given are not exactly correct as this would necessitate lengthy calculations which would not make great enough difference to affect the practical usefulness of the table:

Cylinder of 100 Cu. Ft. Capacity at 68° Fahr.

Gauge Pressure	Volume Remaining	Gauge Pressure	Volume Remaining

1800	100	700	39
1620	90	500	28
1440	80	300	17
1260	70	100	6
1080	60	18	1
900	50	9	1/2

Cylinder of 250 Cu. Ft. Capacity at 68° Fahr.

Gauge Pressure	Volume Remaining	Gauge Pressure	Volume Remaining
1800	250	700	97
1620	225	500	70
1440	200	300	42
1260	175	100	15
1080	150	18	8
900	125	9	1-1/4

The temperature of the cylinder affects the pressure in a large degree, the pressure increasing with a rise in temperature and falling with a fall in temperature. The variation for a 100 cubic foot cylinder at various temperatures is given in the following tabulation:

At 150° Fahr........................ 2090 pounds.
At 100° Fahr........................ 1912 pounds.
At 80° Fahr........................ 1844 pounds.
At 68° Fahr........................ 1800 pounds.
At 50° Fahr........................ 1736 pounds.
At 32° Fahr........................ 1672 pounds.
At 0 Fahr........................ 1558 pounds.
At -10° Fahr........................ 1522 pounds.

Chlorate of Potash Method._--In spite of its higher cost and the inferior gas produced, the chlorate of potash method of producing oxygen is used to a limited extent when it is impossible to secure the gas in cylinders.

An iron retort (Figure 8) is arranged to receive about fifteen pounds of chlorate of potash mixed with three pounds of manganese dioxide, after which the cylinder is closed with a tight cap, clamped on. This retort is carried above a burner using fuel gas or other means of generating heat and this burner is lighted after the chemical charge is mixed and compressed in the tube.

The generation of gas commences and the oxygen is led through water baths which wash and cool it before storing in a tank connected with the plant. From this tank the gas is compressed into portable cylinders at a pressure of about 300 pounds to the square inch for use as required in welding operations.

Each pound of chlorate of potash liberates about three cubic feet of oxygen, and taking everything into consideration, the cost of gas produced in this way is several times that of the purer product secured by the liquid air process.

These chemical generators are oftentimes a source of great danger, especially when used with or near the acetylene gas generator, as is sometimes the case with cheap portable outfits. Their use should not be tolerated when any other method is available, as the danger from accident alone should prohibit the practice except when properly installed and cared for away from other sources of combustible gases.

ACETYLENE

In 1862 a chemist, Woehler, announced the discovery of the preparation of acetylene gas from calcium carbide, which he had made by heating to a high temperature a mixture of charcoal with an alloy of zinc and calcium. His product would decompose water and yield the gas. For nearly thirty years these substances were neglected, with the result that acetylene was practically unknown, and up to 1892 an acetylene flame was seen by very few persons and its possibilities were not dreamed of. With the development of the modern electric furnace the possibility of calcium carbide as a commercial product became known.

In the above year, Thomas L. Willson, an electrical engineer of Spray, North Carolina, was experimenting in an attempt to prepare metallic calcium, for which purpose he employed an electric furnace operating on a mixture of lime and coal tar with about ninety-five horse power. The result was a molten mass which became hard and brittle when cool. This apparently useless product was discarded and thrown in a nearby stream, when, to the astonishment of onlookers, a large volume of gas was immediately liberated, which, when ignited, burned with a bright and smoky flame and gave off quantities of soot. The solid material proved to be calcium carbide and the gas acetylene.

Thus, through the incidental study of a by-product, and as the result of an accident, the possibilities in carbide were made known, and in the spring of 1895 the first factory in the world for the production of this substance was established by the Willson Aluminum Company.

When water and calcium carbide are brought together an action takes place which results in the formation of acetylene gas and slaked lime.

CARBIDE

Calcium carbide is a chemical combination of the elements carbon and calcium, being dark brown, black or gray with sometimes a blue or red tinge. It looks like stone and will only burn when heated with oxygen.

Calcium carbide may be preserved for any length of time if protected from the air, but the ordinary moisture in the atmosphere gradually affects it until nothing remains but slaked lime. It always possesses a penetrating odor, which is not due to the carbide itself but to the fact that it is being constantly affected by moisture and producing small quantities of acetylene gas.

This material is not readily dissolved by liquids, but if allowed to come in contact with water, a decomposition takes place with the evolution of large quantities of gas. Carbide is not affected by shock, jarring or age.

A pound of absolutely pure carbide will yield five and one-half cubic feet of acetylene. Absolute purity cannot be attained commercially, and in practice good carbide will produce from four and one-half to five cubic feet for each pound used.

Carbide is prepared by fusing lime and carbon in the electric furnace under a heat in excess of 6,000 degrees Fahrenheit. These materials are among the most difficult to melt that are known. Lime is so infusible that it is frequently employed for the materials of crucibles in which the highest melting metals are fused, and for the pencils in the calcium light because it will stand extremely high temperatures.

Carbon is the material employed in the manufacture of arc light electrodes and other electrical appliances that must stand extreme heat. Yet these two substances are forced into combination in the manufacture of calcium carbide. It is the excessively high temperature attainable in the electric furnace that causes this combination and not any effect of the electricity other than the heat produced.

A mixture of ground coke and lime is introduced into the furnace through which an electric arc has been drawn. The materials unite and form an ingot of very pure carbide surrounded by a crust of less purity. The poorer crust is rejected in breaking up the mass into lumps which are graded according to their size. The largest size is 2 by 3-1/2 inches and is called "lump," a medium size is 1/2 by 2 inches and is called "egg," an intermediate size for certain types of generators is 3/8 by 1-1/4 inches and called "nut," and the finely crushed pieces for use in still other types of generators are 1/12 by 1/4 inch in size and are called "quarter." Instructions as to the size best suited to different generators are furnished by the makers of those instruments.

These sizes are packed in air-tight sheet steel drums containing 100 pounds each. The Union Carbide Company of Chicago and New York, operating under patents, manufactures and distributes the supply of calcium carbide for the entire United States. Plants for this manufacture are established at Niagara Falls, New York, and Sault Ste. Marie, Michigan. This company maintains a system of warehouses in more than one hundred and ten cities, where large stocks of all sizes are carried.

The National Board of Fire Underwriters gives the following rules for the storage of carbide:

Calcium carbide in quantities not to exceed six hundred pounds may be stored, when contained in approved metal packages not to exceed one hundred pounds each, inside insured property, provided that the place of storage be dry, waterproof and well ventilated and also provided that all but one of the packages in any one building shall be sealed and that seals shall not be broken so long as there is carbide in excess of one pound in any other unsealed package in the building.

Calcium carbide in quantities in excess of six hundred pounds must be stored above ground in detached buildings, used exclusively for the storage of calcium carbide, in approved metal packages, and such buildings shall be constructed to be dry, waterproof and well ventilated.

Properties of Acetylene._--This gas is composed of twenty-four parts of carbon and two parts of hydrogen by weight and is classed with natural gas, petroleum, etc., as one of the hydrocarbons. This gas contains the highest percentage of carbon known to exist in any combination of this form and it may therefore be considered as gaseous carbon. Carbon is the fuel that is used in all forms of combustion and is present in all fuels from whatever source or in whatever form. Acetylene is therefore the most powerful of all fuel gases and is able to give to the torch flame in welding the highest temperature of any flame.

Acetylene is a colorless and tasteless gas, possessed of a peculiar and penetrating odor. The least trace in the air of a room is easily noticed, and if this odor is detected about an apparatus in operation, it is certain to indicate a leakage of gas through faulty piping, open valves, broken hose or otherwise. This leakage must be prevented before proceeding with the work to be done.

All gases which burn in air will, when mixed with air previous to ignition, produce more or less violent explosions, if fired. To this rule acetylene is no exception. One measure of acetylene and twelve and one-half of air are required for complete combustion; this is therefore the proportion for the most perfect explosion. This is not the only possible mixture that will explode, for all proportions from three to thirty per cent of acetylene in air will explode with more or less force if ignited. The igniting point of acetylene is lower than that of coal gas, being about 900 degrees Fahrenheit as against eleven hundred degrees for coal gas. The gas issuing from a torch will ignite if allowed to play on the tip of a lighted cigar.

It is still further true that acetylene, at some pressures, greater than normal, has under most favorable conditions for the effect, been found to explode; yet it may be stated with perfect confidence that under no circumstances has anyone ever secured an explosion in it when subjected to pressures not exceeding fifteen pounds to the square inch.

Although not exploded by the application of high heat, acetylene is injured by such treatment. It is partly converted, by high heat, into other compounds, thus lessening the actual quantity of the gas, wasting it and polluting the rest by the introduction of substances which do not belong there. These compounds remain in part with the gas, causing it to burn with a persistent smoky flame and with the deposit of objectionable tarry substances. Where the gas is generated without undue rise of temperature these difficulties are avoided.

Purification of Acetylene._--Impurities in this gas are caused by impurities in the calcium carbide from which it is made or by improper methods and lack of care in generation. Impurities from the material will be considered first.

Impurities in the carbide may be further divided into two classes: those which exert no action on water and those which act with the water to throw off other gaseous products which remain in the acetylene. Those impurities which exert no action on the water consist of coke that has not been changed in the furnace and sand and some other substances which are harmless except that they increase the ash left after the acetylene has been generated.

An analysis of the gas coming from a typical generator is as follows:

	Per cent
Acetylene	99.36
Oxygen	.08
Nitrogen	.11
Hydrogen	.06
Sulphuretted Hydrogen	.17
Phosphoretted Hydrogen	.04
Ammonia	.10
Silicon Hydride	.03
Carbon Monoxide	.01
Methane	.04

The oxygen, nitrogen, hydrogen, methane and carbon monoxide are either harmless or are present in such small quantities as to be neglected. The phosphoretted hydrogen and silicon hydride are self-inflammable gases when exposed to the air, but their quantity is so very small that this possibility may be dismissed. The ammonia and sulphuretted hydrogen are almost entirely dissolved by the water used in the gas generator. The surest way to avoid impure gas is to use high-grade calcium carbide in the generator and the carbide of American manufacture is now so pure that it never causes trouble.

The first and most important purification to which the gas is subjected is its passage through the body of water in the generator as it bubbles to the top. It is then filtered through felt to remove the solid particles of lime dust and other impurities which float in the gas.

Further purification to remove the remaining ammonia, sulphuretted hydrogen and phosphorus containing compounds is accomplished by chemical means. If this is considered necessary it can be easily accomplished by readily available purifying apparatus which can be attached to any generator or inserted between the generator and torch outlets. The following mixtures have been used.

"_Heratol,_" a solution of chromic acid or sulphuric acid absorbed in porous earth.

"_Acagine,_" a mixture of bleaching powder with fifteen per cent of lead chromate.

"_Puratylene,_" a mixture of bleaching powder and hydroxide of lime, made very porous, and containing from eighteen to twenty per cent of active chlorine.

"_Frankoline,_" a mixture of cuprous and ferric chlorides dissolved in strong hydrochloric acid absorbed in infusorial earth.

A test for impure acetylene gas is made by placing a drop of ten per cent solution of silver nitrate on a white blotter and holding the paper in a stream of gas coming from the torch tip. Blackening of the paper in a short length of time indicates impurities.

Acetylene in Tanks._--Acetylene is soluble in water to a very limited extent, too limited to be of practical use. There is only one liquid that possesses sufficient power of containing acetylene in solution to be of commercial value, this being the liquid acetone. Acetone is produced in various ways, oftentimes from the distillation of wood. It is a transparent, colorless liquid that flows with ease. It boils at 133° Fahrenheit, is inflammable and burns with a luminous flame. It has a peculiar but rather agreeable odor.

Acetone dissolves twenty-four times its own bulk of acetylene at ordinary atmospheric pressure. If this pressure is increased to two atmospheres, 14.7 pounds above ordinary pressure, it will dissolve just twice as much of the gas and for each atmosphere that the pressure is increased it will dissolve as much more.

If acetylene be compressed above fifteen pounds per square inch at ordinary temperature without first being dissolved in acetone a danger is present of self-ignition. This danger, while practically nothing at fifteen pounds, increases with the pressure until at forty atmospheres it is very explosive. Mixed with acetone, the gas loses this dangerous property and is safe for handling and transportation. As acetylene is dissolved in the liquid the acetone increases its volume slightly so that when the gas has been drawn out of a closed tank a space is left full of free acetylene.

This last difficulty is removed by first filling the cylinder or tank with some porous material, such as asbestos, wood charcoal, infusorial earth, etc. Asbestos is used in practice and by a system of packing and supporting the absorbent material no space is left for the free gas, even when the acetylene has been completely withdrawn.

The acetylene is generated in the usual way and is washed, purified and dried. Great care is used to make the gas as free as possible from all impurities and from air. The gas is forced into containers filled with acetone as described and is compressed to one hundred and fifty pounds to the square inch. From these tanks it is transferred to the smaller portable cylinders for consumers' use.

The exact volume of gas remaining in a cylinder at atmospheric temperature may be calculated if the weight of the cylinder empty is known. One pound of the gas occupies 13.6 cubic feet, so that if the difference in weight between the empty cylinder and the one considered be multiplied by 13.6. the result will be the number of cubic feet of gas contained.

The cylinders contain from 100 to 500 cubic feet of acetylene under pressure. They cannot be filled with the ordinary type of generator as they require special purifying and compressing apparatus, which should never be installed in any building where other work is being carried on, or near other buildings which are occupied, because of the danger of explosion.

Dissolved acetylene is manufactured by the Prest-O-Lite Company, the Commercial Acetylene Company and the Searchlight Gas Company and is distributed from warehouses in various cities.

These tanks should not be discharged at a rate per hour greater than one-seventh of their total capacity, that is, from a tank of 100 cubic feet capacity, the discharge should not be more than fourteen cubic feet per hour. If discharge is carried on at an excessive rate the acetone is drawn out with the gas and reduces the heat of the welding flame.

For this reason welding should not be attempted with cylinders designed for automobile and boat lighting. When the work demands a greater delivery than one of the larger tanks will give, two or more tanks may be connected with a special coupler such as may be secured from the makers and distributers of the gas. These couplers may be arranged for two, three, four or five tanks in one battery by removing the plugs on the body of the coupler and attaching additional connecting pipes. The coupler body carries a pressure gauge and the valve for controlling the pressure of the gas as it flows to the welding torches. The following capacities should be provided for:

Acetylene Consumption of Torches per Hour	Combined Capacity of Cylinders in Use
Up to 15 feet	100 cubic feet
16 to 30 feet	200 cubic feet
31 to 45 feet	300 cubic feet
46 to 60 feet	400 cubic feet
61 to 75 feet	500 cubic feet

WELDING RODS

The best welding cannot be done without using the best grade of materials, and the added cost of these materials over less desirable forms is so slight when compared to the quality of work performed and the waste of gases with inferior supplies, that it is very unprofitable to take any chances in this respect. The makers of welding equipment carry an assortment of supplies that have been standardized and that may be relied upon to produce the desired result when properly used. The safest plan is to secure this class of material from the makers.

Welding rods, or welding sticks, are used to supply the additional metal required in the body of the weld to replace that broken or cut away and also to add to the joint whenever possible so that the work may have the same or greater strength than that found in the original piece. A rod of the same material as that being welded is used when both parts of the work are the same. When dissimilar metals are to be joined rods of a composition suited to the work are employed.

These filling rods are required in all work except steel of less than 16 gauge. Alloy iron rods are used for cast iron. These rods have a high silicon content, the silicon reacting with the carbon in the iron to produce a softer and more easily machined weld than would otherwise be the case. These rods are often made so that they melt at a slightly lower point than cast iron. This is done for the reason that when the part being welded has been brought to the fusing heat by the torch, the filling material can be instantly melted in without allowing the parts to cool. The metal can be added faster and more easily controlled.

Rods or wires of Norway iron are used for steel welding in almost all cases. The purity of this grade of iron gives a homogeneous, soft weld of even texture, great ductility and exceptionally good machining qualities.
For welding heavy steel castings, a rod of rolled carbon steel is employed.
For working on high carbon steel, a rod of the steel being welded must be employed and for alloy steels, such as nickel, manganese, vanadium, etc., special rods of suitable alloy composition are preferable.

Aluminum welding rods are made from this metal alloyed to give the even flowing that is essential. Aluminum is one of the most difficult of all the metals to handle in this work and the selection of the proper rod is of great importance.

Brass is filled with brass wire when in small castings and sheets. For general work with brass castings, manganese bronze or Tobin bronze may be used.

Bronze is welded with manganese bronze or Tobin bronze, while copper is filled with copper wire.

These welding rods should always be used to fill the weld when the thickness of material makes their employment necessary, and additional metal should always be added at the weld when possible as the joint cannot have the same strength as the original piece if made or dressed off flush with the surfaces around the weld. This is true because the metal welded into the joint is a casting and will never have more strength than a casting of the material used for filling.

Great care should be exercised when adding metal from welding rods to make sure that no metal is added at a point that is not itself melted and molten when the addition is made. When molten metal is placed upon cooler surfaces the result is not a weld but merely a sticking together of the two parts without any strength in the joint.

FLUXES

Difficulty would be experienced in welding with only the metal and rod to work with because of the scale that forms on many materials under heat, the oxides of other metals and the impurities found in almost all metals. These things tend to prevent a perfect joining of the metals and some means are necessary to prevent their action.

Various chemicals, usually in powder form, are used to accomplish the result of cleaning the weld and making the work of the operator less difficult. They are called fluxes.

A flux is used to float off physical impurities from the molten metal; to furnish a protecting coating around the weld; to assist in the removal of any objectionable oxide of the metals being handled; to lower the temperature at which the materials flow; to make a cleaner weld and to produce a better quality of metal in the finished work.

The flux must be of such composition that it will accomplish the desired result without introducing new difficulties. They may be prepared by the operator in many cases or may be secured from the makers of welding apparatus, the same remarks applying to their quality as were made regarding the welding rods, that is, only the best should be considered.

The flux used for cast iron should have a softening effect and should prevent burning of the metal. In many cases it is possible and even preferable to weld cast iron without the use of a flux, and in any event the smaller the quantity used the better the result should be. Flux should not be added just before the completion of the work because the heat will not have time to drive the added elements out of the metal or to incorporate them with the metal properly.

Aluminum should never be welded without using a flux because of the oxide formed. This oxide, called alumina, does not melt until a heat of 5,000° Fahrenheit is reached, four times the heat needed to melt the aluminum itself. It is necessary that this oxide be broken down or dissolved so that the aluminum may have a chance to flow together. Copper is another metal that requires a flux because of its rapid oxidation under heat.

While the flux is often thrown or sprinkled along the break while welding, much better results will be obtained by dipping the hot end of the welding rod into the flux whenever the work needs it. Sufficient powder will stick on the end of the rod for all purposes, and with some fluxes too much will adhere. Care should always be used to avoid the application of excessive flux, as this is usually worse than using too little.

SUPPLIES AND FIXTURES

Goggles._--The oxy-acetylene torch should not be used without the protection to the eyes afforded by goggles. These not only relieve unnecessary strain, but make it much easier to watch the exact progress of the work with the molten metal. The difficulty of protecting the sight while welding is even greater than when cutting metal with the torch.

Acetylene gives a light which is nearest to sunlight of any artificial illuminant. But for the fact that this gas light gives a little more green and less blue in its composition, it would be the same in quality and practically the same in intensity. This light from the gas is almost absent during welding, being lost with the addition of the extra oxygen needed to produce the welding heat. The light that is dangerous comes from the molten metal which flows under the torch at a bright white heat.

Goggles for protection against this light and the heat that goes with it may be secured in various tints, the darker glass being for welding and the lighter for cutting. Those having frames in which the metal parts do not touch the flesh directly are most desirable because of the high temperature reached by these parts.

Gloves._--While not as necessary as are the goggles, gloves are a convenience in many cases. Those in which leather touches the hands directly are really of little value as the heat that protection is desired against makes the leather so hot that nothing is gained in comfort. Gloves are made with asbestos cloth, which are not open to this objection in so great a degree.

[Illustration: Figure 9.--Frame for Welding Stand]

Tables and Stands._--Tables for holding work while being welded (Figure 9) are usually made from lengths of angle steel welded together. The top should be rectangular, about two feet wide and two and one-half feet long. The legs should support the working surface at a height of thirty-two to thirty-six inches from the floor. Metal lattice work may be fastened or laid in the top framework and used to support a layer of firebrick bound together with a mixture of one-third cement and two-thirds fireclay. The piece being welded is braced and supported on this table with pieces of firebrick so that it will remain stationary during the operation.

Holders for supporting the tanks of gas may be made or purchased in forms that rest directly on the floor or that are mounted on wheels. These holders are quite useful where the floor or ground is very uneven.

Hose._--All permanent lines from tanks and generators to the torches are made with piping rigidly supported, but the short distance from the end of the pipe line to the torch itself is completed with a flexible hose so that the operator may be free in his movements while welding. An accident through which the gases mix in the hose and are ignited will burst this part of the equipment, with more or less painful results to the person handling it. For that reason it is well to use hose with great enough strength to withstand excessive pressure.

A poor grade of hose will also break down inside and clog the flow of gas, both through itself and through the parts of the torch. To avoid outside damage and cuts this hose is sometimes encased with coiled sheet metal. Hose may be secured with a bursting strength of more than 1,000 pounds to the square inch. Many operators prefer to distinguish between the oxygen and acetylene lines by their color and to allow this, red is used for the oxygen and black for acetylene.

Other Materials._--Sheet asbestos and asbestos fibre in flakes are used to cover parts of the work while preparing them for welding and during the operation itself. The flakes and small pieces that become detached from the large sheets are thrown into a bin where the completed small work is placed to allow slow and even cooling while protected by the asbestos.

Asbestos fibre and also ordinary fireclay are often used to make a backing or mould into a form that may be placed behind aluminum and some other metals that flow at a low heat and which are accordingly difficult to handle under ordinary methods. This forms a solid mould into which the metal is practically cast as melted by the torch so that the desired shape is secured without danger of the walls of metal breaking through and flowing away.

Carbon blocks and rods are made in various shapes and sizes so that they may be used to fill threaded holes and other places that it is desired to protect during welding. These may be secured in rods of various diameters up to one inch and in blocks of several different dimensions.