How to Weld & Cut Steel

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PREFACE

In the preparation of this work, the object has
been to cover not only the

several processes of welding, but also those
other processes which are so

closely allied in method and results as to make
them a part of the whole

subject of joining metal to metal with the aid of
heat.

The workman who wishes to handle his trade from
start to finish finds that

it is necessary to become familiar with certain
other operations which

precede or follow the actual joining of the metal
parts, the purpose of

these operations being to add or retain certain
desirable qualities in the

materials being handled. For this reason the
following subjects have been

included: Annealing, tempering, hardening, heat treatment and the

restoration of steel.

In order that the user may understand the underlying principles and the

materials employed in this work, much practical information is given on the

uses and characteristics of the various metals; on the production, handling

and use of the gases and other materials which are a part of the equipment;

and on the tools and accessories for the production and handling of these

materials.

An examination will show that the greatest usefulness of this book lies in

the fact that all necessary information and data has been included in one

volume, making it possible for the workman to use one source for securing a knowledge of both principle and practice, preparation and finishing of the

work, and both large and small repair work as well as manufacturing methods

used in metal working.

An effort has been made to eliminate all matter which is not of direct

usefulness in practical work, while including all that those engaged in

this trade find necessary. To this end, the descriptions have been limited

to those methods and accessories which are found in actual use today. For

the same reason, the work includes the application of the rules laid down

by the insurance underwriters which govern this work as well as

instructions for the proper care and handling of the generators, torches

and materials found in the shop.

Special attention has been given to definite directions for handling the

different metals and alloys which must be handled. The instructions have

been arranged to form rules which are placed in the order of their use

during the work described and the work has been subdivided in such a way

that it will be found possible to secure information on any one point

desired without the necessity of spending time in other fields.

The facts which the expert welder and metalworker finds it most necessary

to have readily available have been secured, and prepared especially for

this work, and those of most general use have been combined with the

chapter on welding practice to which they apply.

The size of this volume has been kept as small as possible, but an

examination of the alphabetical index will show that the range of subjects

and details covered is complete in all respects. This has been accomplished

through careful classification of the contents and the elimination of all

repetition and all theoretical, historical and similar matter that is not

absolutely necessary.

Free use has been made of the information given by those manufacturers who

are recognized as the leaders in their respective fields, thus insuring

that the work is thoroughly practical and that it represents present day

methods and practice.

THE AUTHOR.

CONTENTS

OXY-ACETYLENE WELDING AND CUTTING, ELECTRIC AND THERMIT WELDING

CHAPTER I

METALS AND THEIR ALLOYS—HEAT TREATMENT

THE METALS

Iron.—Iron, in its pure state, is a soft, white,

easily worked

metal. It is the most important of all the metallic elements, and is, next

to aluminum, the commonest metal found in the earth.

Mechanically speaking, we have three kinds of iron: wrought iron, cast iron

and steel. Wrought iron is very nearly pure iron; cast iron contains carbon

and silicon, also chemical impurities; and steel contains a definite

proportion of carbon, but in smaller quantities than cast iron.

Pure iron is never obtained commercially, the metal always being mixed with

various proportions of carbon, silicon, sulphur, phosphorus, and other

elements, making it more or less suitable for different purposes. Iron is

magnetic to the extent that it is attracted by magnets, but it does not

retain magnetism itself, as does steel. Iron forms, with other elements,

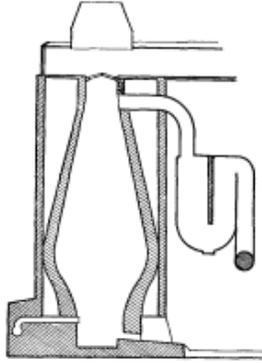many important combinations, such as its alloys, oxides, and sulphates.

Image Figure 1.—Section Through a Blast Furnace

Cast Iron.—Metallic iron is separated from iron ore in the blast

furnace (Figure 1), and when allowed to run into moulds is called cast

iron. This form is used for engine cylinders and pistons, for brackets,

covers, housings and at any point where its brittleness is not

objectionable. Good cast iron breaks with a gray fracture, is free from

blowholes or roughness, and is easily machined, drilled, etc. Cast iron is

slightly lighter than steel, melts at about 2,400 degrees in practice, is

about one-eighth as good an electrical conductor as copper and has a

tensile strength of 13,000 to 30,000 pounds per square inch. Its

compressive strength, or resistance to crushing, is very great. It has

excellent wearing qualities and is not easily warped and deformed by heat.

Chilled iron is cast into a metal mould so that the outside is cooled

quickly, making the surface very hard and difficult to cut and giving great

resistance to wear. It is used for making cheap gear wheels and parts that

must withstand surface friction.

Malleable Cast Iron.—This is often called simply malleable iron. It

is a form of cast iron obtained by removing much of the carbon from cast

iron, making it softer and less brittle. It has a

tensile strength of

25,000 to 45,000 pounds per square inch, is easily machined, will stand a

small amount of bending at a low red heat and is used chiefly in making

brackets, fittings and supports where low cost is of considerable

importance. It is often used in cheap constructions in place of steel

forgings. The greatest strength of a malleable casting, like a steel

forging, is in the surface, therefore but little machining should be done.

Wrought Iron.—This grade is made by treating the cast iron to

remove almost all of the carbon, silicon, phosphorus, sulphur, manganese

and other impurities. This process leaves a small amount of the slag from

the ore mixed with the wrought iron.

Wrought iron is used for making bars to be machined into various parts. If

drawn through the rolls at the mill once, while being made, it is called

"muck bar;" if rolled twice, it is called "merchant bar" (the commonest

kind), and a still better grade is made by rolling a third time. Wrought

iron is being gradually replaced in use by mild rolled steels.

Wrought iron is slightly heavier than cast iron, is a much better

electrical conductor than either cast iron or steel, has a tensile strength

of 40,000 to 60,000 pounds per square inch and costs slightly more than

steel. Unlike either steel or cast iron, wrought iron does not harden when

cooled suddenly from a red heat.

Grades of Irons.—The mechanical properties of cast iron differ

greatly according to the amount of other materials it contains. The most

important of these contained elements is carbon, which is present to a

degree varying from 2 to 5-1/2 per cent. When iron containing much carbon

is quickly cooled and then broken, the fracture is nearly white in color

and the metal is found to be hard and brittle. When the iron is slowly

cooled and then broken the fracture is gray and the iron is more malleable

and less brittle. If cast iron contains sulphur or phosphorus, it will show

a white fracture regardless of the rapidity of cooling, being brittle and

less desirable for general work.

Steel.—Steel is composed of extremely minute particles of iron and

carbon, forming a network of layers and bands. This carbon is a smaller

proportion of the metal than found in cast iron, the percentage being from

3/10 to 2-1/2 per cent.

Carbon steel is specified according to the number of "points" of carbon, a

point being one one-hundredth of one per cent of the weight of the steel.

Steel may contain anywhere from 30 to 250 points, which is equivalent to

saying, anywhere from 3/10 to 2-1/2 per cent, as above. A 70-point steel

would contain 70/100 of one per cent or 7/10 of one per cent of carbon by

weight. The percentage of carbon determines the hardness of the steel, also

many other qualities, and its suitability for various kinds of work. The

more carbon contained in the steel, the harder the metal will be, and, of

course, its brittleness increases with the hardness. The smaller the grains

or particles of iron which are separated by the carbon, the stronger the

steel will be, and the control of the size of these particles is the object

of the science of heat treatment.

In addition to the carbon, steel may contain the following:

Silicon, which increases the hardness, brittleness, strength and difficulty

of working if from 2 to 3 per cent is present.

Phosphorus, which hardens and weakens the metal

but makes it easier to

cast. Three-tenths per cent of phosphorus serves as a hardening agent and

may be present in good steel if the percentage of carbon is low. More

than this weakens the metal.

Sulphur, which tends to make the metal hard and filled with small holes.

Manganese, which makes the steel so hard and tough that it can with

difficulty be cut with steel tools. Its hardness is not lessened by

annealing, and it has great tensile strength.

Alloy steel has a varying but small percentage of other elements mixed with

it to give certain desired qualities. Silicon steel and manganese steel are

sometimes classed as alloy steels. This subject is taken up in the latter

part of this chapter under Alloys, where the various combinations

and their characteristics are given consideration.

Steel has a tensile strength varying from 50,000 to 300,000 pounds per

square inch, depending on the carbon percentage and the other alloys

present, as well as upon the texture of the grain. Steel is heavier than

cast iron and weighs about the same as wrought iron. It is about one-ninth

as good a conductor of electricity as copper.

Steel is made from cast iron by three principal processes: the crucible,

Bessemer and open hearth.

Crucible steel is made by placing pieces of iron in a clay or

graphite crucible, mixed with charcoal and a small amount of any desired

alloy. The crucible is then heated with coal, oil or gas fires until the

iron melts, and, by absorbing the desired elements and giving up or

changing its percentage of carbon, becomes steel. The molten steel is then

poured from the crucible into moulds or bars for use. Crucible steel may

also be made by placing crude steel in the crucibles in place of the iron.

This last method gives the finest grade of metal and the crucible process

in general gives the best grades of steel for mechanical use.
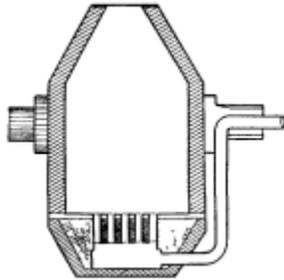
Image Figure 2.—A Bessemer Converter

Bessemer steel is made by heating iron until all the undesirable

elements are burned out by air blasts which furnish the necessary oxygen.

The iron is placed in a large retort called a converter, being poured,

while at a melting heat, directly from the blast furnace into the

converter. While the iron in the converter is molten, blasts of air are

forced through the liquid, making it still hotter and burning out the

impurities together with the carbon and manganese. These two elements are

then restored to the iron by adding spiegeleisen (an alloy of iron, carbon

and manganese). A converter holds from 5 to 25 tons of metal and requires

about 20 minutes to finish a charge. This makes the cheapest steel.

Image Figure 3.—An Open Hearth Furnace

Open hearth steel is made by placing the molten iron in a receptacle

while currents of air pass over it, this air having itself been highly

heated by just passing over white hot brick (Figure. 3). Open hearth steel

is considered more uniform and reliable than Bessemer, and is used for

springs, bar steel, tool steel, steel plates, etc.

Aluminum is one of the commonest industrial metals. It is used for
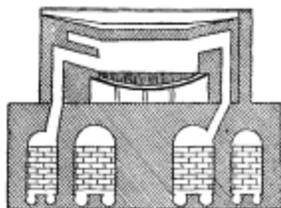
gear cases, engine crank cases, covers, fittings, and wherever lightness

and moderate strength are desirable.

Aluminum is about one-third the weight of iron and about the same weight as

glass and porcelain; it is a good electrical conductor (about one-half as

good as copper); is fairly strong itself and gives great strength to other

metals when alloyed with them. One of the greatest advantages of aluminum

is that it will not rust or corrode under ordinary conditions. The granular

formation of aluminum makes its strength very unreliable and it is too soft

to resist wear.

Copper is one of the most important metals used in the trades, and

the best commercial conductor of electricity, being exceeded in this

respect only by silver, which is but slightly better. Copper is very

malleable and ductile when cold, and in this state may be easily worked

under the hammer. Working in this way makes the copper stronger and harder,

but less ductile. Copper is not affected by air, but acids cause the

formation of a green deposit called verdigris.

Copper is one of the best conductors of heat, as well as electricity, being

used for kettles, boilers, stills and wherever this quality is desirable.

Copper is also used in alloys with other metals,

forming an important part

of brass, bronze, german silver, bell metal and gun metal. It is about

one-eighth heavier than steel and has a tensile strength of about 25,000 to

50,000 pounds per square inch.

Lead.—The peculiar properties of lead, and especially its quality

of showing but little action or chemical change in the presence of other

elements, makes it valuable under certain conditions of use. Its principal

use is in pipes for water and gas, coverings for roofs and linings for vats

and tanks. It is also used to coat sheet iron for similar uses and as an

important part of ordinary solder.

Lead is the softest and weakest of all the commercial metals, being very

pliable and inelastic. It should be remembered that lead and all its

compounds are poisonous when received into the system. Lead is more than

one-third heavier than steel, has a tensile strength of only about 2,000

pounds per square inch, and is only about one-tenth as good a conductor of

electricity as copper.

Zinc.—This is a bluish-white metal of crystalline form. It is

brittle at ordinary temperatures and becomes malleable at about 250 to 300

degrees Fahrenheit, but beyond this point becomes even more brittle than at

ordinary temperatures. Zinc is practically unaffected by air or moisture

through becoming covered with one of its own compounds which immediately

resists further action. Zinc melts at low temperatures, and when heated

beyond the melting point gives off very poisonous fumes.

The principal use of zinc is as an alloy with other metals to form brass,

bronze, german silver and bearing metals. It is also used to cover the

surface of steel and iron plates, the plates

being then called galvanized.

Zinc weighs slightly less than steel, has a tensile strength of 5,000

pounds per square inch, and is not quite half as good as copper in

conducting electricity.

Tin resembles silver in color and luster. Tin is ductile and

malleable and slightly crystalline in form, almost as heavy as steel, and

has a tensile strength of 4,500 pounds per square inch.

The principal use of tin is for protective platings on household utensils

and in wrappings of tin-foil. Tin forms an important part of many alloys

such as babbitt, Britannia metal, bronze, gun metal and bearing metals.

Nickel is important in mechanics because of its combinations with

other metals as alloys. Pure nickel is grayish-white, malleable, ductile

and tenacious. It weighs almost as much as steel and, next to manganese, is

the hardest of metals. Nickel is one of the three magnetic metals, the

others being iron and cobalt. The commonest alloy containing nickel is

german silver, although one of its most important alloys is found in nickel

steel. Nickel is about ten per cent heavier than steel, and has a tensile

strength of 90,000 pounds per square inch.

Platinum.—This metal is valuable for two reasons: it is not

affected by the air or moisture or any ordinary acid or salt, and in

addition to this property it melts only at the highest temperatures. It is

a fairly good electrical conductor, being better than iron or steel. It is

nearly three times as heavy as steel and its tensile strength is 25,000

pounds per square inch.

ALLOYS

An alloy is formed by the union of a metal with

some other material, either

metal or non-metallic, this union being composed of two or more elements

and usually brought about by heating the substances together until they

melt and unite. Metals are alloyed with materials which have been found to

give to the metal certain characteristics which are desired according to

the use the metal will be put to.

The alloys of metals are, almost without exception, more important from an

industrial standpoint than the metals themselves. There are innumerable

possible combinations, the most useful of which are here classed under the

head of the principal metal entering into their composition.

Steel.—Steel may be alloyed with almost any of the metals or

elements, the combinations that have proven valuable numbering more than a

score. The principal ones are given in alphabetical order, as follows:

Aluminum is added to steel in very small amounts for the purpose of

preventing blow holes in castings.

Boron increases the density and toughness of the metal.

Bronze, added by alloying copper, tin and iron, is used for gun metal.

Carbon has already been considered under the head of steel in the section

devoted to the metals. Carbon, while increasing the strength and hardness,

decreases the ease of forging and bending and decreases the magnetism and

electrical conductivity. High carbon steel can be welded only with

difficulty. When the percentage of carbon is low, the steel is called "low

carbon" or "mild" steel. This is used for rods and shafts, and called

"machine" steel. When the carbon percentage is high, the steel is called

"high carbon" steel, and it is used in the shop as tool steel. One-tenth

per cent of carbon gives steel a tensile strength of 50,000 to 65,000

pounds per square inch; two-tenths per cent gives from 60,000 to 80,000;

four-tenths per cent gives 70,000 to 100,000, and six-tenths per cent

gives 90,000 to 120,000.

Chromium forms chrome steel, and with the further addition of nickel is

called chrome nickel steel. This increases the hardness to a high degree

and adds strength without much decrease in ductility. Chrome steels are

used for high-speed cutting tools, armor plate, files, springs, safes,

dies, etc.

Manganese has been mentioned under Steel. Its alloy is much used for

high-speed cutting tools, the steel hardening when cooled in the air and

being called self-hardening.

Molybdenum is used to increase the hardness to a high degree and makes the

steel suitable for high-speed cutting and gives it self-hardening

properties.

Nickel, with which is often combined chromium, increases the strength,

springiness and toughness and helps to prevent corrosion.

Silicon has already been described. It suits the metal for use in

high-speed tools.

Silver added to steel has many of the properties of nickel.

Tungsten increases the hardness without making the steel brittle. This

makes the steel well suited for gas engine valves as it resists corrosion

and pitting. Chromium and manganese are often used in combination with

tungsten when high-speed cutting tools are made.

Vanadium as an alloy increases the elastic limit, making the steel

stronger, tougher and harder. It also makes the steel able to stand much

bending and vibration.

Copper.—The principal copper alloys include brass, bronze, german

silver and gun metal.

Brass is composed of approximately one-third zinc and two-thirds copper. It

is used for bearings and bushings where the speeds are slow and the loads

rather heavy for the bearing size. It also finds use in washers, collars

and forms of brackets where the metal should be non-magnetic, also for many

highly finished parts.

Brass is about one-third as good an electrical conductor as copper, is

slightly heavier than steel and has a tensile strength of 15,000 pounds

when cast and about 75,000 to 100,000 pounds when drawn into wire.

Bronze is composed of copper and tin in various proportions, according to

the use to which it is to be put. There will always be from six-tenths to

nine-tenths of copper in the mixture. Bronze is used for bearings,

bushings, thrust washers, brackets and gear wheels. It is heavier than

steel, about 1/15 as good an electrical conductor as pure copper and has a

tensile strength of 30,000 to 60,000 pounds.

Aluminum bronze, composed of copper, zinc and aluminum has high tensile

strength combined with ductility and is used for parts requiring this

combination.

Bearing bronze is a variable material, its composition and proportion

depending on the maker and the use for which it is designed. It usually

contains from 75 to 85 per cent of copper combined with one or more

elements, such as tin, zinc, antimony and lead.

White metal is one form of bearing bronze containing over 80 per cent of

zinc together with copper, tin, antimony and lead. Another form is made

with nearly 90 per cent of tin combined with copper and antimony.

Gun metal bronze is made from 90 per cent copper with 10 per cent of tin

and is used for heavy bearings, brackets and highly finished parts.

Phosphor bronze is used for very strong castings and bearings. It is

similar to gun metal bronze, except that about 1-1/2 per cent of phosphorus

has been added.

Manganese bronze contains about 1 per cent of manganese and is used for

parts requiring great strength while being free from corrosion.

German silver is made from 60 per cent of copper with 20 per cent each of

zinc and nickel. Its high electrical resistance makes it valuable for

regulating devices and rheostats.

Tin is the principal part of babbitt and solder. A

commonly used babbitt is composed of 89 per cent tin, 8 per cent antimony

and 3 per cent of copper. A grade suitable for repairing is made from

80 per cent of lead and 20 per cent antimony. This last formula should not

be used for particular work or heavy loads, being more suitable for

spacers. Innumerable proportions of metals are marketed under the name of

babbitt.

Solder is made from 50 per cent tin and 50 per cent lead, this grade being

called "half-and-half." Hard solder is made from two-thirds tin and

one-third lead.

Aluminum forms many different alloys, giving increased strength to whatever

metal it unites with.

Aluminum brass is composed of approximately 65 per cent copper, 30 per cent

zinc and 5 per cent aluminum. It forms a metal with high tensile strength

while being ductile and malleable.

Aluminum zinc is suitable for castings which must be stiff and hard.

Nickel aluminum has a tensile strength of 40,000

pounds per square inch.

Magnalium is a silver-white alloy of aluminum with from 5 to 20 per cent of

magnesium, forming a metal even lighter than aluminum and strong enough to

be used in making high-speed gasoline engines.

HEAT TREATMENT OF STEEL

The processes of heat treatment are designed to suit the steel for various

purposes by changing the size of the grain in the metal, therefore the

strength; and by altering the chemical composition of the alloys in the

metal to give it different physical properties. Heat treatment, as applied

in ordinary shop work, includes the three processes of annealing, hardening

and tempering, each designed to accomplish a certain definite result.

All of these processes require that the metal treated be gradually brought

to a certain predetermined degree of heat which shall be uniform throughout

the piece being handled and, from this point, cooled according to certain

rules, the selection of which forms the difference in the three methods.

Annealing.—This is the process which relieves all internal strains

and distortion in the metal and softens it so that it may more easily be

cut, machined or bent to the required form. In some cases annealing is used

only to relieve the strains, this being the case after forging or welding

operations have been performed. In other cases it is only desired to soften

the metal sufficiently that it may be handled easily. In some cases both of

these things must be accomplished, as after a piece has been forged and

must be machined. No matter what the object, the procedure is the same.

The steel to be annealed must first be heated to a dull red. This heating

should be done slowly so that all parts of the

piece have time to reach the

same temperature at very nearly the same time. The piece may be heated in

the forge, but a much better way is to heat in an oven or furnace of some

type where the work is protected against air currents, either hot or cold,

and is also protected against the direct action of the fire.

Image Figure 4.—A Gaspipe Annealing Oven

Probably the simplest of all ovens for small tools is made by placing a

piece of ordinary gas pipe in the fire (Figure 4), and heating until the

inside of the pipe is bright red. Parts placed in this pipe, after one end

has been closed, may be brought to the desired heat without danger of

cooling draughts or chemical change from the action of the fire. More

elaborate ovens may be bought which use gas, fuel oils or coal to produce

the heat and in which the work may be placed on trays so that the fire will

not strike directly on the steel being treated.

If the work is not very important, it may be withdrawn from the fire or

oven, after heating to the desired point, and allowed to cool in the air

until all traces of red have disappeared when held in a dark place. The

work should be held where it is reasonably free from cold air currents. If,

upon touching a pine stick to the piece being annealed, the wood does not

smoke, the work may then be cooled in water.

Better annealing is secured and harder metal may be annealed if the cooling

is extended over a number of hours by placing the work in a bed of

non-heat-conducting material, such as ashes, charred bone, asbestos fiber,

lime, sand or fire clay. It should be well covered with the heat retaining

material and allowed to remain until cool. Cooling may be accomplished by

allowing the fire in an oven or furnace to die down and go out, leaving the

work inside the oven with all openings closed. The greater the time taken

for gradual cooling from the red heat, the more perfect will be the results

of the annealing.

While steel is annealed by slow cooling, copper or brass is annealed by

bringing to a low red heat and quickly plunging into cold water.

Hardening.—Steel is hardened by bringing to a proper temperature,

slowly and evenly as for annealing, and then cooling more or less quickly,

according to the grade of steel being handled. The degree of hardening is

determined by the kind of steel, the temperature from which the metal is

cooled and the temperature and nature of the bath into which it is plunged

for cooling.

Steel to be hardened is often heated in the fire until at some heat around

600 to 700 degrees is reached, then placed in a heating bath of molten

lead, heated mercury, fused cyanate of potassium, etc., the heating bath

itself being kept at the proper temperature by fires acting on it. While

these baths have the advantage of heating the metal evenly and to exactly

the temperature desired throughout without any part becoming over or under

heated, their disadvantages consist of the fact that their materials and

the fumes are poisonous in most all cases, and if not poisonous, are

extremely disagreeable.

The degree of heat that a piece of steel must be brought to in order that

it may be hardened depends on the percentage of carbon in the steel. The

greater the percentage of carbon, the lower the heat necessary to harden.

Image Figure 5.—Cooling the Test Bar for Hardening

To find the proper heat from which any steel must be cooled, a simple test

may be carried out provided a sample of the steel, about six inches long

can be secured. One end of this test bar should be heated almost to its

melting point, and held at this heat until the other end just turns red.

Now cool the piece in water by plunging it so that both ends enter at the

same time (Figure 5), that is, hold it parallel with the surface of the

water when plunged in. This serves the purpose of cooling each point along

the bar from a different heat. When it has cooled in the water remove the

piece and break it at short intervals, about ½ inch, along its length.

The point along the test bar which was cooled from the best possible

temperature will show a very fine smooth grain and the piece cannot be cut

by a file at this point. It will be necessary to remember the exact color

of that point when taken from the fire, making another test if necessary,

and heat all pieces of this same steel to this heat. It will be necessary

to have the cooling bath always at the same temperature, or the results

cannot be alike.

While steel to be hardened is usually cooled in water, many other liquids

may be used. If cooled in strong brine, the heat will be extracted much

quicker, and the degree of hardness will be greater. A still greater degree

of hardness is secured by cooling in a bath of mercury. Care should be used

with the mercury bath, as the fumes that arise are poisonous.

Should toughness be desired, without extreme hardness, the steel may be

cooled in a bath of lard oil, neatsfoot oil or fish oil. To secure a result

between water and oil, it is customary to place a thick layer of oil on top

of water. In cooling, the piece will pass through the oil first, thus

avoiding the sudden shock of the cold water, yet producing a degree of

hardness almost as great as if the oil were not used.

It will, of course, be necessary to make a separate test for each cooling

medium used. If the fracture of the test piece shows a coarse grain, the

steel was too hot at that point; if the fracture can be cut with a file,

the metal was not hot enough at that point.

When hardening carbon tool steel its heat should be brought to a cherry

red, the exact degree of heat depending on the amount of carbon and the

test made, then plunged into water and held there until all hissing sound

and vibration ceases. Brine may be used for this purpose; it is even better

than plain water. As soon as the hissing stops, remove the work from the

water or brine and plunge in oil for complete cooling.

Image Figure 6.—Cooling the Tool for Tempering

In hardening high-speed tool steel, or air hardening steels, the tool

should be handled as for carbon steel, except that after the body reaches

a cherry red, the cutting point must be quickly brought to a white heat,

almost melting, so that it seems ready for welding. Then cool in an oil

bath or in a current of cool air.

Hardening of copper, brass and bronze is accomplished by hammering or

working them while cold.

Tempering is the process of making steel tough after it has been

hardened, so that it will hold a cutting edge and resist cracking.

Tempering makes the grain finer and the metal stronger. It does not affect

the hardness, but increases the elastic limit and reduces the brittleness

of the steel. In that tempering is usually performed immediately after

hardening, it might be considered as a continuation of the former process.

The work or tool to be tempered is slowly heated to a cherry red and the

cutting end is then dipped into water to a depth of ½ to ¾ inch above

the point (Figure 6). As soon as the point cools, still leaving the tool

red above the part in water, remove the work from the bath and quickly rub

the end with a fine emery cloth.

As the heat from the uncooled part gradually heats the point again, the

color of the polished portion changes rapidly. When a certain color is

reached, the tool should be completely immersed in the water until cold.

For lathe, planer, shaper and slotter tools, this color should be a light

straw.

Reamers and taps should be cooled from an ordinary straw color.

Drills, punches and wood working tools should have a brown color.

Blue or light purple is right for cold chisels and screwdrivers.

Dark blue should be reached for springs and wood saws.

Darker colors than this, ranging through green and gray, denote that the

piece has reached its ordinary temper, that is, it is partially annealed.

After properly hardening a spring by dipping in lard or fish oil, it should

be held over a fire while still wet with the oil. The oil takes fire and

burns off, properly tempering the spring.

Remember that self-hardening steels must never be dipped in water, and

always remember for all work requiring degrees of heat, that the more

carbon, the less heat.

Case Hardening.—This is a process for adding more carbon to the

surface of a piece of steel, so that it will have good wear-resisting

qualities, while being tough and strong on the inside. It has the effect of

forming a very hard and durable skin on the surface of soft steel, leaving

the inside unaffected.

The simplest way, although not the most efficient, is to heat the piece to

be case hardened to a red heat and then sprinkle or rub the part of the

surface to be hardened with potassium ferrocyanide. This material is a

deadly poison and should be handled with care. Allow the cyanide to fuse on

the surface of the metal and then plunge into water, brine or mercury.

Repeating the process makes the surface harder and the hard skin deeper

each time.

Another method consists of placing the piece to be hardened in a bed of

powdered bone (bone which has been burned and then powdered) and cover with

more powdered bone, holding the whole in an iron tray. Now heat the tray

and bone with the work in an oven to a bright red

heat for 30 minutes to an

hour and then plunge the work into water or brine.

CHAPTER II

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 with

increasing 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.
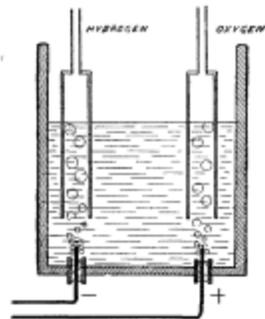

Image Figure 7.—Obtaining Oxygen by Electrolysis

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	½

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

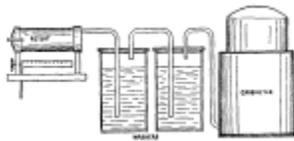used to a limited extent when it is impossible to secure the gas in

cylinders.

Image Figure 8.—Oxygen from Chlorate of Potash

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 ½ 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 ¼ 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

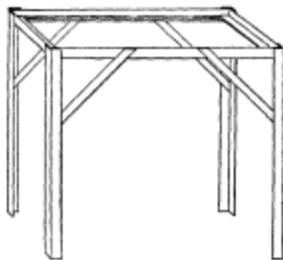are made with asbestos cloth, which are not open to this objection in so

great a degree.

Image 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 fiber 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 fiber 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.

CHAPTER III

ACETYLENE GENERATORS

Acetylene generators used for producing the gas from the action of water on

calcium carbide are divided into three principal classes according to the

pressure under which they operate.

Low pressure generators are designed to operate at one pound or less per

square inch. Medium pressure systems deliver the gas at not to exceed

fifteen pounds to the square inch while high pressure types furnish gas

above fifteen pounds per square inch. High pressure systems are almost

unknown in this country, the medium pressure type being often referred to

as "high pressure."

Another important distinction is formed by the method of bringing the

carbide and water together. The majority of those now in use operate by

dropping small quantities of carbide into a large volume of water, allowing

the generated gas to bubble up through the water before being collected

above the surface. This type is known as the "carbide to water" generator.

A less used type brings a measured and small quantity of water to a

comparatively large body of the carbide, the gas being formed and collected

from the chamber in which the action takes place. This is called the "water

to carbide" type. Another way of expressing the difference in feed is that

of designating the two types as "carbide feed" for the former and "water

feed" for the latter.

A further division of the carbide to water machines is made by mentioning

the exact method of feeding the carbide. One type, called "gravity feed"

operates by allowing the carbide to escape and fall by the action of its

own weight, or gravity; the other type, called "forced feed," includes a

separate mechanism driven by power. This mechanism feeds definite amounts

of the carbide to the water as required by the demands on the generator.

The action of either feed is controlled by the withdrawal of gas from the

generator, the aim being to supply sufficient carbide to maintain a nearly

constant supply.

Generator Requirements.—The qualities of a good generator are

outlined as follows: [Footnote: See Pond's "Calcium Carbide and

Acetylene."]

It must allow no possibility of the existence of an explosive mixture in

any of its parts at any time. It is not enough to

argue that a mixture,

even if it exists, cannot be exploded unless kindled. It is necessary to

demand that a dangerous mixture can at no time be formed, even if the

machine is tampered with by an ignorant person. The perfect machine must be

so constructed that it shall be impossible at any time, under any

circumstances, to blow it up.

It must insure cool generation. Since this is a relative term, all machines

being heated somewhat during the generation of gas, this amounts to saying

that a machine must heat but little. A pound of carbide decomposed by water

develops the same amount of heat under all circumstances, but that heat

can be allowed to increase locally to a high point, or it can be equalized

by water so that no part of the material becomes heated enough to do

damage.

It must be well constructed. A good generator does not need, perhaps, to be

"built like a watch," but it should be solid, substantial and of good

material. It should be built for service, to last and not simply to sell;

anything short of this is to be avoided as unsafe and unreliable.

It must be simple. The more complicated the machine the sooner it will get

out of order. Understand your generator. Know what is inside of it and

beware of an apparatus, however attractive its exterior, whose interior is

filled with pipes and tubes, valves and diaphragms whose functions you do

not perfectly understand.

It should be capable of being cleaned and recharged and of receiving all

other necessary attention without loss of gas, both for economy's sake, and

more particularly to avoid danger of fire.

It should require little attention. All machines have to be emptied and

recharged periodically; but the more this process is simplified and the
more quickly this can be accomplished, the better.

It should be provided with a suitable indicator to designate how low the
charge is in order that the refilling may be done in good season.

It should completely use up the carbide, generating the maximum amount of
gas.

Overheating.—A large amount of heat is liberated when acetylene gas
is formed from the union of calcium carbide and water. Overheating during
this process, that is to say, an intense local heat rather than a large
amount of heat well distributed, brings about the phenomenon of
polymerization, converting the gas, or part of it, into oily matters, which
can do nothing but harm. This tarry mass coming through the small openings
in the torches causes them to become partly closed and alters the
proportions of the gases to the detriment of the welding flame. The only
remedy for this trouble is to avoid its cause and secure cool generation.

Overheating can be detected by the appearance of the sludge remaining after
the gas has been made. Discoloration, yellow or brown, shows that there has
been trouble in this direction and the resultant effects at the torches may
be looked for. The abundance of water in the carbide to water machines
effects this cooling naturally and is a characteristic of well designed
machines of this class. It has been found best and has practically become a
fundamental rule of generation that a gallon of water must be provided for
each pound of carbide placed in the generator. With this ratio and a
generator large enough for the number of torches to be supplied, little
trouble need be looked for with overheating.

Water to Carbide Generators.—It is, of course, much easier to

obtain a measured and regular flow of water than to obtain such a flow of

any solid substance, especially when the solid substance is in the form of

lumps, as is carbide This fact led to the use of a great many water-feed

generators for all classes of work, and this type is still in common use

for the small portable machines, such, for instance, as those used on motor

cars for the lamps. The water-feed machine is not, however, favored for

welding plants, as is the carbide feed, in spite of the greater

difficulties attending the handling of the solid material.

A water-feed generator is made up of the gas producing part and a holder

for the acetylene after it is made. The carbide is held in a tray formed of

a number of small compartments so that the charge in each compartment is

nearly equal to that in each of the others. The water is allowed to flow

into one of these compartments in a volume sufficient to produce the

desired amount of gas and the carbide is completely used from this one

division. The water then floods the first compartment and finally overflows

into the next one, where the same process is repeated. After using the

carbide in this division, it is flooded in turn and the water passing on to

those next in order, uses the entire charge of the whole tray.

These generators are charged with the larger sizes of carbide and are

easily taken care of. The residue is removed in the tray and emptied,

making the generator ready for a fresh supply of carbide.

Carbide to Water Generators.—This type also is made up of two

principal parts, the generating chamber and a gas holder, the holder being

part of the generating chamber or a separate device. The generator (Figure

10) contains a hopper to receive the charge of carbide and is fitted with

the feeding mechanism to drop the proper amount of carbide into the water

as required by the demands of the torches. The charge of carbide is of one

of the smaller sizes, usually "nut" or "quarter."

Feed Mechanisms.—The device for dropping the carbide into the water

is the only part of the machine that is at all complicated. This

complication is brought about by the necessity of controlling the mass of

carbide so that it can never be discharged into the water at an excessive

rate, feeding it at a regular rate and in definite amounts, feeding it

positively whenever required and shutting off the feed just as positively

when the supply of gas in the holder is enough for the immediate needs.
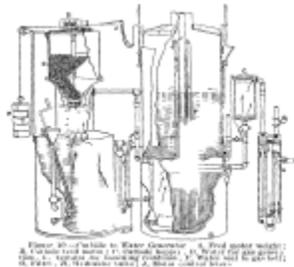

Image Figure 10.—Carbide to Water Generator. A. Feed motor weight;

B. Carbide feed motor; C. Carbide hopper; D. Water for gas generation;

E. Agitator for loosening residuum; F. Water seal in gas bell; G. Filter;

H. Hydraulic Valve; J. Motor control levers.

The charge of carbide is unavoidably acted upon by the water vapor in the

generator and will in time become more or less pasty and sticky. This is

more noticeable if the generator stands idle for a considerable length of

time This condition imposes another duty on the feeding mechanism; that is,

the necessity of self-cleaning so that the

carbide, no matter in what

condition, cannot prevent the positive action of this part of the device,

especially so that it cannot prevent the supply from being stopped at the

proper time.

The gas holder is usually made in the bell form so that the upper portion

rises and falls with the addition to or withdrawal from the supply of gas

in the holder. The rise and fall of this bell is often used to control the

feed mechanism because this movement indicates positively whether enough

gas has been made or that more is required. As the bell lowers it sets the

feed mechanism in motion, and when the gas passing into the holder has

raised the bell a sufficient distance, the movement causes the feed

mechanism to stop the fall of carbide into the water. In practice, the

movement of this part of the holder is held within very narrow limits.

Gas Holders.—No matter how close the adjustment of the feeding

device, there will always be a slight amount of gas made after the fall of

carbide is stopped, this being caused by the evolution of gas from the

carbide with which water is already in contact. This action is called

"after generation" and the gas holder in any type of generator must

provide sufficient capacity to accommodate this excess gas. As a general

rule the water to carbide generator requires a larger gas holder than the

carbide to water type because of the greater amount of carbide being acted

upon by the water at any one time, also because the surface of carbide

presented to the moist air within the generating chamber is greater with

this type.

Freezing.—Because of the rather large body of water contained in

any type of generator, there is always danger of its freezing and

rendering the device inoperative unless placed in a temperature above the

freezing point of the water. It is, of course, dangerous and against the

insurance rules to place a generator in the same room with a fire of any

kind, but the room may be heated by steam or hot water coils from a furnace

in another building or in another part of the same building.

When the generator is housed in a separate structure the walls should be

made of materials or construction that prevents the passage of heat or

cold through them to any great extent. This may be accomplished by the use

of hollow tile or concrete blocks or by any other form of double wall

providing air spaces between the outer and inner facings. The space between

the parts of the wall may be filled with materials that further retard the

loss of heat if this is necessary under the conditions prevailing.

Residue From Generators.—The sludge remaining in the carbide to

water generator may be drawn off into the sewer if the piping is run at a

slant great enough to give a fall that carries the whole quantity, both

water and ash, away without allowing settling and consequent clogging.

Generators are provided with agitators which are operated to stir the ash

up with the water so that the whole mass is carried off when the drain cock

is opened.

If sewer connections cannot be made in such a way that the ash is entirely

carried away, it is best to run the liquid mass into a settling basin

outside of the building. This should be in the form of a shallow pit which

will allow the water to pass off by soaking into the ground and by

evaporation, leaving the comparatively dry ash in

the pit. This ash which

remains is essentially slaked lime and can often be disposed of to more or

less advantage to be used in mortar, whitewash, marking paths and any other

use for which slaked lime is suited. The disposition of the ash depends

entirely on local conditions. An average analysis of this ash is as

follows:

Sand........................ 1.10 per cent.

Carbon..................... 2.72   "

Oxide of iron and alumina.. 2.77   "

Lime....................... 64.06   "

Water and carbonic acid.... 29.35   "

100.00

GENERATOR CONSTRUCTION

The water for generating purposes is carried in the large tank-like

compartment directly below the carbide chamber. See Figure 11. This water

compartment is filled through a pipe of such a height that the water level

cannot be brought above the proper point or else the water compartment is

provided with a drain connection which accomplishes this same result by

allowing an excess to flow away.

The quantity of water depends on the capacity of the generator inasmuch as

there must be one gallon for each pound of carbide required. The generator

should be of sufficient capacity to furnish gas under working conditions

from one charge of carbide to all torches installed for at least five hours

continuous use.

After calculating the withdrawal of the whole number of torches according

to the work they are to do for this period of five hours the proper

generator capacity may be found on the basis of one cubic foot of gas per

hour for each pound of carbide. Thus if the torches were to use sixty cubic

feet of gas per hour, five hours would call for three hundred cubic feet

and a three hundred pound generator should be installed. Generators are

rated according to their carbide capacity in pounds.

Charging.—The carbide capacity of the generator should be great

enough to furnish a continuous supply of gas for the maximum operating

time, basing the quantity of gas generated on four and one-half cubic feet

from each pound of lump carbide and on four cubic feet from each pound of

quarter, intermediate sizes being in proportion.

Generators are built in such a way that it is impossible for the acetylene

to escape from the gas holding compartment during the recharging process.

This is accomplished (1) by connecting the water inlet pipe opening with a

shut off valve in such a way that the inlet cannot be uncovered or opened

without first closing the shut off valve with the same movement of the

operator; (2) by incorporating an automatic or hydraulic one-way valve so

that this valve closes and acts as a check when the gas attempts to flow

from the holder back to the generating chamber, or by any other means that

will positively accomplish this result.

In generators having no separate gas holding chamber but carrying the

supply in the same compartment in which it is generated, the gas contained

under pressure is allowed to escape through vent pipes into the outside

air before recharging with carbide. As in the former case, the parts are

so interlocked that it is impossible to introduce carbide or water without

first allowing the escape of the gas in the generator.

It is required by the insurance rules that the entire change of carbide

while in the generator be held in such a way that it may be entirely

removed without difficulty in case the necessity should arise.

Generators should be cleaned and recharged at regular stated intervals.

This work should be done during daylight hours only and likewise all

repairs should be made at such a time that artificial light is not needed.

Where it is absolutely necessary to use artificial light it should be

provided only by incandescent electric lamps enclosed in gas tight globes.

In charging generating chambers the old ash and all residue must first be

cleaned out and the operator should be sure that no drain or other pipe has

become clogged. The generator should then be filled with the required

amount of water. In charging carbide feed machines be careful not to place

less than a gallon of water in the water compartment for each pound of

carbide to be used and the water must be brought to, but not above, the

proper level as indicated by the mark or the maker's instructions. The

generating chamber must be filled with the proper amount of water before

any attempt is made to place the carbide in its holder. This rule must

always be followed. It is also necessary that all automatic water seals

and valves, as well as any other water tanks, be filled with clean water

at this time.

Never recharge with carbide without first cleaning the generating chamber

and completely refilling with clean water. Never test the generator or

piping for leaks with any flame, and never apply flame to any open pipe or

at any point other than the torch, and only to the torch after it has a

welding or cutting nozzle attached. Never use a lighted match, lamp,

candle, lantern, cigar or any open flame near a generator. Failure to

observe these precautions is liable to endanger

life and property.

Operation and Care of Generators.—The following instructions apply

especially to the Davis Bournonville pressure generator, illustrated in

Figure 11. The motor feed mechanism is illustrated in Figure 12.

Before filling the machine, the cover should be removed and the hopper

taken out and examined to see that the feeding disc revolves freely; that

no chains have been displaced or broken, and that the carbide displacer

itself hangs barely free of the feeding disc when it is revolved. After

replacing the cover, replace the bolts and tighten them equally, a little

at a time all around the circumference of the cover—not screwing tight in

one place only. Do not screw the cover down any more than is necessary to

make a tight fit.

To charge the generator, proceed as follows: Open the vent valve by turning

the handle which extends over the filling tube until it stands at a right

angle with the generator. Open the valve in the water filling pipe, and

through this fill with water until it runs out of the overflow pipe of the

drainage chamber, then close the valve in the water filling pipe and vent

valve. Remove the carbide filling plugs and fill the hopper with

1-1/4"x3/8" carbide ("nut" size). Then replace the plugs and the

safety-locking lever chains. Now rewind the motor weight. Run the pressure

up to about five pounds by raising the controlling diaphragm valve lever

by hand (Figure 12, lever marked E). Then raise the blow-off lever,

allowing the gas to blow off until the gauge shows about two pounds; this

to clear the generator of air mixture. Then run the pressure up to about

eight pounds by raising the controlling valve lever E, or until

this controlling lever rests against the upper wing of the fan governor,

and prevents operation of the feed motor. After this is done, the motor

will operate automatically as the gas is consumed.

Image Figure 11.—Pressure Generator (Davis Bournonville).

A, Feed motor weight;

B, Carbide feed motor;

C, Motor Control diaphragm;

D, Carbide hopper;

E, Carbide feed disc;

F, Overflow pipe;

G, Overflow pipe seal;

H, Overflow pipe valve;

J, Filling funnel;

K, Hydraulic valve;

L, Expansion chamber;

M, Escape pipe;

N, Feed pipe;

O, Agitator for residuum;

P, Residuum valve;

Q, Water level

Image Figure 12.—Feed Mechanism of Pressure Generator

Should the pressure rise much above the blow-off point, the safety

controlling diaphragm valve will operate and throw the safety clutch in

interference and thus stop the motor. This interference clutch will then

have to be returned to its former position before the motor will operate,

but cannot be replaced before the pressure has been reduced below the

blow-off point.

The parts of the feed mechanism illustrated in Figure 12 are as follows:

A, motor drum for weight cable. B, carbide filling plugs.

C, chains for connecting safety locking lever of motor to pins on

the top of the carbide plugs. D, interference clutch of motor.

E, lever on feed controlling diaphragm valve. F, lever of

interference controlling diaphragm valve that operates interference clutch.

G, feed controlling diaphragm valve. H, diaphragm valve

controlling operation of interference clutch. I, interference pin

to engage emergency clutch. J, main shaft driving carbide feeding

disc. Y, safety locking lever.

Recharging Generator.—Turn the agitator handle rapidly for several

revolutions, and then open the residuum valve, having five or six pounds

gas pressure on the machine. If the carbide charge has been exhausted and

the motor has stopped, there is generally enough carbide remaining in the

feeding disc that can be shaken off, and fed by running the motor to

obtain some pressure in the generator. The desirability of discharging

the residuum with some gas pressure is because the pressure facilitates

the discharge and at the same time keeps the generator full of gas,

preventing air mixture to a great extent. As soon as the pressure is

relieved by the withdrawal of the residuum, the vent valve should be

opened, as if the pressure is maintained until all of the residuum is

discharged gas would escape through the discharge valve.

Having opened the vent pipe valve and relieved the pressure, open the

valve in the water filling tube. Close the residuum valve, then run in

several gallons of water and revolve the agitator, after which draw out the

remaining residuum; then again close the residuum valve and pour in water

until it discharges from the overflow pipe of the drainage chamber. It is

desirable in filling the generator to pour the

water in rapidly enough to

keep the filling pipe full of water, so that air will not pass in at the

same time.

After the generator is cleaned and filled with water, fill with carbide and

proceed in the same manner as when first charging.

Carbide Feed Mechanism.—Any form of carbide to water machine should

be so designed that the carbide never falls directly from its holder into

the water, but so that it must take a more or less circuitous path. This

should be true, no matter what position the mechanism is in. One of the

commonest types of forced feed machine carries the carbide in a hopper with

slanting sides, this hopper having a large opening in the bottom through

which the carbide passes to a revolving circular plate. As the pieces of

carbide work out toward the edge of the plate under the influence of the

mass behind them, they are thrown off into the water by small stationary

fins or plows which are in such a position that they catch the pieces

nearest the edges and force them off as the plate revolves. This

arrangement, while allowing a free passage for the carbide, prevents an

excess from falling should the machine stop in any position.

When, as is usually the case, the feed mechanism is actuated by the rise

or fall of pressure in the generator or of the level of some part of the

gas holder, it must be built in such a way that the feeding remains

inoperative as long as the filling opening on the carbide holder remains

open.

The feed of carbide should always be shut off and controlled so that under

no condition can more gas be generated than could be cared for by the

relief valve provided. It is necessary also to have the feed mechanism at

least ten inches above the surface of the water so that the parts will

never become clogged with damp lime dust.

Motor Feed.—The feed mechanism itself is usually operated by power

secured from a slowly falling weight which, through a cable, revolves a

drum. To this drum is attached suitable gearing for moving the feed parts

with sufficient power and in the way desired. This part, called the motor,

is controlled by two levers, one releasing a brake and allowing the motor

to operate the feed, the other locking the gearing so that no more carbide

will be dropped into the water. These levers are moved either by the

quantity of gas in the holder or by the pressure of the gas, depending on

the type of machine.

With a separate gas holder, such as used with low pressure systems, the

levers are operated by the rise and fall of the bell of the holder or

gasometer, alternately starting and stopping the motor as the bell falls

and rises again. Medium pressure generators are provided with a diaphragm

to control the feed motor.

This diaphragm is carried so that the pressure within the generator acts

on one side while a spring, whose tension is under the control of the

operator, acts on the other side. The diaphragm is connected to the brake

and locking device on the motor in such a way that increasing the tension

on the spring presses the diaphragm and moves a rod that releases the brake

and starts the feed. The gas pressure, increasing with the continuation of

carbide feed, acts on the other side and finally overcomes the pressure of

the spring tension, moving the control rod the other way and stopping the

motor and carbide feed. This spring tension is adjusted and checked with

the help of a pressure gauge attached to the generating chamber.

Gravity Feed.—This type of feed differs from the foregoing in that

the carbide is simply released and is allowed to fall into the water

without being forced to do so. Any form of valve that is sufficiently

powerful in action to close with the carbide passing through is used and is

operated by the power secured from the rise and fall of the gas holder

bell. When this valve is first opened the carbide runs into the water until

sufficient pressure and volume of gas is generated to raise the bell. This

movement operates the arm attached to the carbide shut off valve and slowly

closes it. A fall of the bell occasioned by gas being withdrawn again opens

the valve and more gas is generated.

Mechanical Feed.—The previously described methods of feeding

carbide to the water have all been automatic in action and do not depend

on the operator for their proper action.

Some types of large generating plants have a power-driven feed, the power

usually being from some kind of motor other than one operated by a weight,

such as a water motor, for instance. This motor is started and stopped by

the operator when, in his judgment, more gas is wanted or enough has been

generated. This type of machine, often called a "non-automatic generator,"

is suitable for large installations and is attached to a gas holder of

sufficient size to hold a day's supply of acetylene. The generator can then

be operated until a quantity of gas has been made that will fill the large

holder, or gasometer, and then allowed to remain idle for some time.

Gas Holders.—The commonest type of gas container is that known as a

gasometer. This consists of a circular tank partly filled with water, into

which is lowered another circular tank, inverted, which is made enough

smaller in diameter than the first one so that three-quarters of an inch is

left between them. This upper and inverted portion, called the bell,

receives the gas from the generator and rises or falls in the bath of water

provided in the lower tank as a greater or less amount of gas is contained

in it.

These holders are made large enough so that they will provide a means of

caring for any after generation and so that they maintain a steady and even

flow. The generator, however, must be of a capacity great enough so that

the gas holder will not be drawn on for part of the supply with all torches

in operation. That is, the holder must not be depended on for a reserve

supply.

The bell of the holder is made so that when full of gas its lower edge is

still under a depth of at least nine inches of water in the lower tank. Any

further rise beyond this point should always release the gas, or at least

part of it, to the escape pipe so that the gas will under no circumstances

be forced into the room from, between the bell and tank. The bell is guided

in its rise and fall by vertical rods so that it will not wedge at any

point in its travel.

A condensing chamber to receive the water which condenses from the

acetylene gas in the holder is usually placed under this part and is

provided with a drain so that this water of condensation may be easily

removed.

Filtering.—A small chamber containing some closely packed but

porous material such as felt is placed in the

pipe leading to the torch

lines. As the acetylene gas passes through this filter the particles of

lime dust and other impurities are extracted from it so that danger of

clogging the torch openings is avoided as much as possible.

The gas is also filtered to a large extent by its passage through the water

in the generating chamber, this filtering or "scrubbing" often being

facilitated by the form of piping through which the gas must pass from the

generating chamber into the holder. If the gas passes out of a number of

small openings when going into the holder the small bubbles give a better

washing than large ones would.

Piping.—Connections from generators to service pipes should

preferably be made with right and left couplings or long thread nipples

with lock nuts. If unions are used, they should be of a type that does not

require gaskets. The piping should be carried and supported so that any

moisture condensing in the lines will drain back toward the generator and

where low points occur they should be drained through tees leading into

drip cups which are permanently closed with screw caps or plugs. No pet

cocks should be used for this purpose.

For the feed pipes to the torch lines the following pipe sizes are

recommended.

3/8 inch pipe. 26 feet long. 2 cubic feet per hour.

½ inch pipe. 30 feet long. 4 cubic feet per hour.

¾ inch pipe. 50 feet long. 15 cubic feet per hour.

1   inch pipe. 70 feet long. 27 cubic feet per hour.

1-1/4 inch pipe. 100 feet long. 50 cubic feet per hour.

1-1/2 inch pipe. 150 feet long. 65 cubic feet

per hour.

2   inch pipe. 200 feet long. 125 cubic feet per hour.

2-1/2 inch pipe. 300 feet long. 190 cubic feet per hour.

3   inch pipe. 450 feet long. 335 cubic feet per hour.

When drainage is possible into a sewer, the generator should not be

connected directly into the sewer but should first discharge into an open

receptacle, which may in turn be connected to the sewer.

No valves or pet cocks should open into the generator room or any other

room when it would be possible, by opening them for draining purposes, to

allow any escape of gas. Any condensation must be removed without the use

of valves or other working parts, being drained into closed receptacles. It

should be needless to say that all the piping for gas must be perfectly

tight at every point in its length.

Safety Devices.—Good generators are built in such a way that the

operator must follow the proper order of operation in charging and cleaning

as well as in all other necessary care. It has been mentioned that the gas

pressure is released or shut off before it is possible to fill the water

compartment, and this same idea is carried further in making the generator

inoperative and free from gas pressure before opening the residue drain of

the carbide filling opening on top of the hopper. Some machines are made so

that they automatically cease to generate should there be a sudden and

abnormal withdrawal of gas such as would be caused by a bad leak. This

method of adding safety by automatic means and interlocking parts may be

carried to any extent that seems desirable or necessary to the maker.

All generators should be provided with escape or relief pipes of large size

which lead to the open air. These pipes are carried so that condensation

will drain back toward the generator and after being led out of the

building to a point at least twelve feet above ground, they end in a

protecting hood so that no rain or solid matter can find its way into them.

Any escape of gas which might ordinarily pass into the generator room is

led into these escape pipes, all parts of the system being connected with

the pipe so that the gas will find this way out.

Safety blow off valves are provided so that any excess gas which cannot be

contained by the gas holder may be allowed to escape without causing an

undue rise in pressure. This valve also allows the escape of pressure above

that for which the generator was designed. Gas released in this way passes

into the escape pipe just described.

Inasmuch as the pressure of the oxygen is much greater than that of the

acetylene when used in the torch, it will be seen that anything that caused

the torch outlet to become closed would allow the oxygen to force the

acetylene back into the generator and the oxygen would follow it, making a

very explosive mixture. This return of the gas is prevented by a hydraulic

safety valve or back pressure valve, as it is often called.

Mechanical check valves have been found unsuitable for this use and those

which employ water as a seal are now required by the insurance rules. The

valve itself (Figure 13) consists of a large cylinder containing water to a

certain depth, which is indicated on the valve body. Two pipes come into

the upper end of this cylinder and lead down into the water, one being

longer than the other. The shorter pipe leads to the escape pipe mentioned

above, while the longer one comes from the generator. The upper end of the

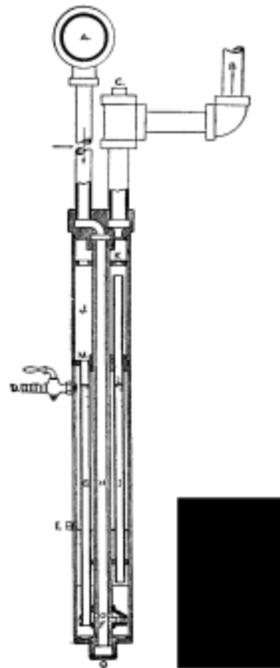cylinder has an opening to which is attached the pipe leading to the

torches.

Image Figure 13.—Hydraulic Back-Pressure Valve.

A, Acetylene supply line;

B, Vent pipe;

C, Water filling plug;

D, Acetylene service cock;

E, Plug to gauge height of water;

F, Gas openings under water;

G, Return pipe for sealing water;

H, Tube to carry gas below water line;

I, Tube to carry gas to escape pipe;

J, Gas chamber;

K, Plug in upper gas chamber;

L, High water level;

M, Opening through which water returns;

O, Bottom clean out casting

The gas coming from the generator through the longer pipe passes out of the

lower end of the pipe which is under water and bubbles up through the water

to the space in the top of the cylinder. From

there the gas goes to the

pipe leading to the torches. The shorter pipe is closed by the depth of

water so that the gas does not escape to the relief pipe. As long as the

gas flows in the normal direction as described there will be no escape to

the air. Should the gas in the torch line return into the hydraulic valve

its pressure will lower the level of water in the cylinder by forcing some

of the liquid up into the two pipes. As the level of the water lowers, the

shorter pipe will be uncovered first, and as this is the pipe leading to

the open air the gas will be allowed to escape, while the pipe leading back

to the generator is still closed by the water seal. As soon as this reverse

flow ceases, the water will again resume its level and the action will

continue. Because of the small amount of water blown out of the escape pipe

each time the valve is called upon to perform this duty, it is necessary to

see that the correct water level is always maintained.

While there are modifications of this construction, the same principle is

used in all types. The pressure escape valve is often attached to this

hydraulic valve body.

Construction Details.—Flexible tubing (except at torches), swing

pipe joints, springs, mechanical check valves, chains, pulleys and lead or

fusible piping should never be used on acetylene apparatus except where the

failure of those parts will not affect the safety of the machine or permit,

either directly or indirectly, the escape of gas into a room. Floats should

not be used except where failure will only render the machine inoperative.

It should be said that the National Board of Fire Underwriters have

established an inspection service for acetylene generators and any

apparatus which bears their label, stating that that particular model and

type has been passed, is safe to use. This service is for the best

interests of all concerned and looks toward the prevention of accidents.

Such inspection is a very important and desirable feature of any outfit and

should be insisted upon.

Location of Generators.—Generators should preferably be placed

outside of insured buildings and in properly constructed generator houses.

The operating mechanism should have ample room to work in and there should

be room enough for the attendant to reach the various parts and perform the

required duties without hindrance or the need of artificial light. They

should also be protected from tampering by unauthorized persons.

Generator houses should not be within five feet of any opening into, nor

have any opening toward, any adjacent building, and should be kept under

lock and key. The size of the house should be no greater than called for by

the requirements mentioned above and it should be well ventilated.

The foundation for the generator itself should be of brick, stone, concrete

or iron, if possible. If of wood, they should be extra heavy, located in a

dry place and open to circulation of air. A board platform is not

satisfactory, but the foundation should be of heavy planking or timber to

make a firm base and so that the air can circulate around the wood.

The generator should stand level and no strain should be placed on any of

the pipes or connections or any parts of the generator proper.

CHAPTER IV

WELDING INSTRUMENTS

VALVES

Tank Valves.—The acetylene tank valve is of the needle type, fitted

with suitable stuffing box nuts and ending in an exposed square shank to

which the special wrench may be fitted when the valve is to be opened or

closed.

The valve used on Linde oxygen cylinders is also a needle type, but of

slightly more complex construction. The body of the valve, which screws

into the top of the cylinder, has an opening below through which the gas

comes from the cylinder, and another opening on the side through which it

issues to the torch line. A needle screws down from above to close this

lower opening. The needle which closes the valve is not connected directly

to the threaded member, but fits loosely into it. The threaded part is

turned by a small hand wheel attached to the upper end. When this hand

wheel is turned to the left, or up, as far as it will go, opening the

valve, a rubber disc is compressed inside of the valve body and this disc

serves to prevent leakage of the gas around the spindle.

The oxygen valve also includes a safety nut having a small hole through it

closed by a fusible metal which melts at 250° Fahrenheit. Melting of this

plug allows the gas to exert its pressure against a thin copper diaphragm,

this diaphragm bursting under the gas pressure and allowing the oxygen to

escape into the air.

The hand wheel and upper end of the valve mechanism are protected during

shipment by a large steel cap which covers them when screwed on to the end

of the cylinder. This cap should always be in place when tanks are received

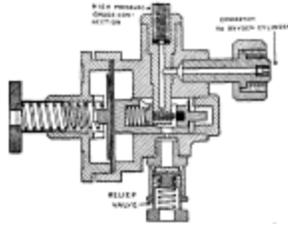from the makers or returned to them.

Image Figure 14.—Regulating Valve

Regulating Valves.—While the pressure in the gas containers may be

anything from zero to 1,800 pounds, and will vary as the gas is withdrawn,

the pressure of the gas admitted to the torch must be held steady and at a

definite point. This is accomplished by various forms of automatic

regulating valves, which, while they differ somewhat in details of

construction, all operate on the same principle.

The regulator body (Figure 14) carries a union which attaches to the side

outlet on the oxygen tank valve. The gas passes through this union,

following an opening which leads to a large gauge which registers the

pressure on the oxygen remaining in the tank and also to a very small

opening in the end of a tube. The gas passes through this opening and into

the interior of the regulator body. Inside of the body is a metal or rubber

diaphragm placed so that the pressure of the incoming gas causes it to

bulge slightly. Attached to the diaphragm is a sleeve or an arm tipped

with a small piece of fiber, the fiber being placed so that it is directly

opposite the small hole through which the gas entered the diaphragm

chamber. The slight movement of the diaphragm draws the fiber tightly over

the small opening through which the gas is entering, with the result that

further flow is prevented.

Against the opposite side of the diaphragm is the end of a plunger. This

plunger is pressed against the diaphragm by a coiled spring. The tension on

the coiled spring is controlled by the operator through a threaded spindle

ending in a wing or milled nut on the outside of the regulator body.

Screwing in on the nut causes the tension on the spring to increase, with a

consequent increase of pressure on the side of the diaphragm opposite to

that on which the gas acts. Inasmuch as the gas pressure acted to close the

small gas opening and the spring pressure acts in the opposite direction

from the gas, it will be seen that the spring pressure tends to keep the

valve open.

When the nut is turned way out there is of course, no pressure on the

spring side of the diaphragm and the first gas coming through automatically

closes the opening through which it entered. If now the tension on the

spring be slightly increased, the valve will again open and admit gas until

the pressure of gas within the regulator is just sufficient to overcome the

spring pressure and again close the opening. There will then be a pressure

of gas within the regulator that corresponds to the pressure placed on the

spring by the operator. An opening leads from the regulator interior to the

torch lines so that all gas going to the torches is drawn from the

diaphragm chamber.

Any withdrawal of gas will, of course, lower the pressure of that remaining

inside the regulator. The spring tension, remaining at the point determined

by the operator, will overcome this lessened pressure of the gas, and the

valve will again open and admit enough more gas to bring the pressure back

to the starting point. This action continues as long as the spring tension

remains at this point and as long as any gas is taken from the regulator.

Increasing the spring tension will require a greater gas pressure to close

the valve and the pressure of that in the regulator will be correspondingly

higher.

When the regulator is not being used, the hand nut should be unscrewed

until no tension remains on the spring, thus closing the valve. After the

oxygen tank valve is open, the regulator hand nut is slowly screwed in

until the spring tension is sufficient to give the required pressure in the

torch lines. Another gauge is attached to the regulator so that it

communicates with the interior of the diaphragm chamber, this gauge showing

the gas pressure going to the torch. It is customary to incorporate a

safety valve in the regulator which will blow off at a dangerous pressure.

In regulating valves and tank valves, as well as all other parts with which

the oxygen comes in contact, it is not permissible to use any form of oil

or grease because of danger of ignition and explosion. The mechanism of a

regulator is too delicate to be handled in the ordinary shop and should any

trouble or leakage develop in this part of the equipment it should be sent

to a company familiar with this class of work for the necessary repairs.

Gas must never be admitted to a regulator until the hand nut is all the way

out, because of danger to the regulator itself and to the operator as well.

A regulator can only be properly adjusted when the tank valve and torch
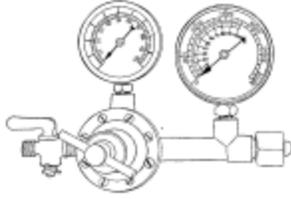
valves are fully opened.

Image Figure 15.—High and Low Pressure Gauges with Regulator

Acetylene regulators are used in connection with tanks of compressed gas.

They are built on exactly the same lines as the oxygen regulating valve and

operate in a similar way. One gauge only, the low pressure indicator, is

used for acetylene regulators, although both high and low pressure may be

used if desired. (See Figure 15.)

TORCHES

Flame is always produced by the combustion of a gas with oxygen and in no

other way. When we burn oil or candles or anything else, the material of

the fuel is first turned to a gas by the heat and is then burned by

combining with the oxygen of the air. If more than a normal supply of air

is forced into the flame, a greater heat and more active burning follows.

If the amount of air, and consequently oxygen, is reduced, the flame

becomes smaller and weaker and the combustion is less rapid. A flame may be

easily extinguished by shutting off all of its air supply.

The oxygen of the combustion only forms one-fifth of the total volume of

air; therefore, if we were to supply pure oxygen in place of air, and in

equal volume, the action would be several times as intense. If the oxygen

is mixed with the fuel gas in the proportion that burns to the very best

advantage, the flame is still further strengthened and still more heat is

developed because of the perfect combustion. The greater the amount of fuel

gas that can be burned in a certain space and within a certain time, the

more heat will be developed from that fuel.

The great amount of heat contained in acetylene gas, greater than that

found in any other gaseous fuel, is used by leading this gas to the

oxy-acetylene torch and there combining it with just the right amount of

oxygen to make a flame of the greatest power and heat than can possibly be

produced by any form of combustion of fuels of this kind. The heat

developed by the flame is about 6300° Fahrenheit and easily melts all the

metals, as well as other solids.

Other gases have been and are now being used in the torch. None of them,

however, produce the heat that acetylene does, and therefore the

oxy-acetylene process has proved the most useful of all. Hydrogen was used

for many years before acetylene was introduced in this field. The

oxy-hydrogen flame develops a heat far below that of oxy-acetylene, namely

4500° Fahrenheit. Coal gas, benzine gas, blaugas and others have also been

used in successful applications, but for the present we will deal

exclusively with the acetylene fuel.

It was only with great difficulty that the obstacles in the way of

successfully using acetylene were overcome by the development of

practicable controlling devices and torches, as well as generators. At

present the oxy-acetylene process is the most universally adaptable, and

probably finds the most widely extended field of usefulness of any welding

process.

The theoretical proportion of the gases for perfect combustion is two and

one-half volumes of oxygen to one of acetylene. In practice this proportion

is one and one-eighth or one and one-quarter

volumes of oxygen to one

volume of acetylene, so that the cost is considerably reduced below what it

would be if the theoretical quantity were really necessary, as oxygen costs

much more than acetylene in all cases.

While the heat is so intense as to fuse anything brought into the path of

the flame, it is localized in the small "welding cone" at the torch tip so

that the torch is not at all difficult to handle without special protection

except for the eyes, as already noted. The art of successful welding may be

acquired by any operator of average intelligence within a reasonable time

and with some practice. One trouble met with in the adoption of this

process has been that the operation looks so simple and so easy of

performance that unskilled and unprepared persons have been tempted to try

welding, with results that often caused condemnation of the process, when

the real fault lay entirely with the operator.

The form of torch usually employed is from twelve to twenty-four inches

long and is composed of a handle at one end with tubes leading from this

handle to the "welding head" or torch proper. At or near one end of the

handle are adjustable cocks or valves for allowing the gases to flow into

the torch or to prevent them from doing so. These cocks are often used for

regulating the pressure and amount of gas flowing to the welding head, but

are not always constructed for this purpose and should not be so used when

it is possible to secure pressure adjustment at the regulators (Figure 16).

Figure 16 shows three different sizes of torches. The number 5 torch is

designed especially for jewelers' work and thin sheet steel welding. It is

eleven inches in length and weighs nineteen ounces. The tips for the number

10 torch are interchangeable with the number 5. The number 10 torch is

adapted for general use on light and medium heavy work. It has six tips and

its length is sixteen inches, with a weight of twenty-three ounces.

The number 15 torch is designed for heavy work, being twenty-five inches in

length, permitting the operator to stand away from the heat of the metal

being worked. These heavy tips are in two parts, the oxygen check being
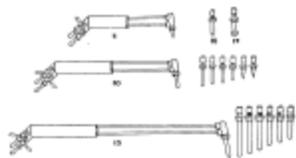
renewable.

Image Figure 16.—Three Sizes of Torches, with Tips

Figures 17 and 18 show two sizes of another welding torch. Still another

type is shown in Figure 19 with four interchangeable tips, the function of

each being as follows:

No. 1. For heavy castings.

No. 2. Light castings and heavy sheet metal.

No. 3. Light sheet metal.

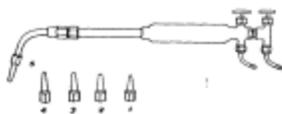No. 4. Very light sheet metal and wire.

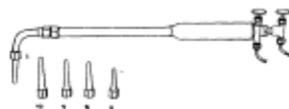Image Figure 17.—Cox Welding Torch (No. 1)

Image Figure 18.—Cox Welding Torch (No. 2)

Image Figure 19.—Monarch Welding Torch

At the side of the shut off cock away from the torch handle the gas tubes

end in standard forms of hose nozzles, to which the rubber hose from the

gas supply tanks or generators can be attached. The tubes from the handle

to the head may be entirely separate from each other, or one may be

contained within the other. As a general rule the upper one of two

separate tubes carries the oxygen, while this gas is carried in the inside

tube when they are concentric with each other.

In the welding head is the mixing chamber designed to produce an intimate

mixture of the two gases before they issue from the nozzle to the flame.

The nozzle, or welding tip, of a suitable size are design for the work to

be handled and the pressure of gases being used, is attached to the welding

head and consists essentially of the passage at the outer end of which the

flame appears.

The torch body and tubes are usually made of brass, although copper is

sometimes used. The joint must be very strong, and are usually threaded and

soldered with silver solder. The nozzle proper is made from copper, because

it withstands the heat of the flame better than other less suitable metals.

The torch must be built in such a way that it is not at all liable to come

apart under the influence of high temperatures.

All torches are constructed in such a way that it is impossible for the

gases to mix by any possible chance before they reach the head, and the

amount of gas contained in the head and tip after being mixed is made as

small as possible. In order to prevent the return of the flame through the

acetylene tube under the influence of the high pressure oxygen some form of

back flash preventer is usually incorporated in the torch at or near the

point at which the acetylene enters. This preventer takes the form of some

porous and heat absorbing material, such as aluminum shavings, contained in

a small cavity through which the gas passes on its way to the head.

High Pressure Torches.—Torches are divided into the same classes as

are the generators; that is, high pressure, medium pressure and low

pressure. As mentioned before, the medium pressure is usually called the

high pressure, because there are very few true high pressure systems in

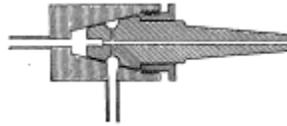use, and comparatively speaking the medium pressure type is one of high

pressure.

Image Figure 20.—H

igh Pressure Torch Head

With a true high pressure torch (Figure 20) the gases are used at very

nearly equal heads so that the mixing before ignition is a simple matter.

This type admits the oxygen at the inner end of a straight passage leading

to the tip of the nozzle. The acetylene comes into this same passage from

openings at one side and near the inner end. The difference in direction of

the two gases as they enter the passage assists in making a homogeneous

mixture. The construction of this nozzle is perfectly simple and is easily

understood. The true high pressure torch nozzle is only suited for use with

compressed and dissolved acetylene, no other gas being at a sufficient

pressure to make the action necessary in mixing the gases.

Medium Pressure Torches.—The medium pressure

(usually called high

pressure) torch (Figure 21) uses acetylene from a medium pressure generator

or from tanks of compressed gas, but will not take the acetylene from low
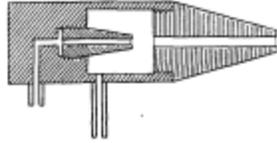
pressure generators.

Image Figure 21.—Medium Pressure Torch Head

The construction of the mixing chamber and nozzle is very similar to that

of the high pressure torch, the gases entering in the same way and from the

same positions of openings. The pressure of the acetylene is but little

lower than that of the oxygen, and the two gases, meeting at right angles,

form a very intimate mixture at this point of juncture. The mixture in its

proportions of gases depends entirely on the sizes of the oxygen and

acetylene openings into the mixing chamber and on the pressures at which

the gases are admitted. There is a very slight injector action as the fast

moving stream of oxygen tends to draw the acetylene from the side openings

into the chamber, but the operation of the torch does not depend on this

action to any extent.

Low Pressure Torches.—The low pressure torch (Figure 22) will use

gas from low pressure generators from medium pressure machines or from

tanks in which it has been compressed and dissolved. This type depends for

a perfect mixture of gas upon the principle of the injector just as it is
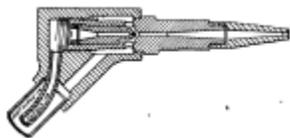
applied in steam boiler practice.

Image Figure 22.—Low Pressure Torch with Separate Injector

Nozzle

The oxygen enters the head at considerable pressure and passes through its

tube to a small jet within the head. The opening of this jet is directly

opposite the end of the opening through the nozzle which forms the mixing

chamber and the path of the gases to the flame. A small distance remains

between the opening from which the oxygen issues and the inner opening into

the mixing passage. The stream of oxygen rushes across this space and

enters the mixing chamber, being driven by its own pressure.

The acetylene enters the head in an annular space surrounding the oxygen

tube. The space between oxygen jet and mixing chamber opening is at one end

of this acetylene space and the stream of oxygen seizes the acetylene and

under the injector action draws it into the mixing chamber, it being

necessary only to have a sufficient supply of acetylene flowing into the

head to allow the oxygen to draw the required proportion for a proper

mixture.

The volume of gas drawn into the mixing chamber depends on the size of the

injector openings and the pressure of the oxygen. In practice the oxygen

pressure is not altered to produce different sized flames, but a new nozzle

is substituted which is designed to give the required flame. Each nozzle

carries its own injector, so that the design is always suited to the

conditions. While torches are made having the injector as a permanent part

of the torch body, the replaceable nozzle is more commonly used because it

makes the one torch suitable for a large range of work and a large number

of different sized flames. With the replaceable head a definite pressure of

oxygen is required for the size being used, this pressure being the one for

which the injector and corresponding mixing chamber were designed in

producing the correct mixture.

Adjustable Injectors.-Another form of low pressure torch operates on

the injector principle, but the injector itself is a permanent part of the

torch, the nozzle only being changed for different sizes of work and flame.

The injector is placed in or near the handle and its opening is the largest

required by any work that can be handled by this particular torch. The

opening through the tip of the injector through which the oxygen issues on

its way to the mixing chamber may be wholly or partly closed by a needle

valve which may be screwed into the opening or withdrawn from it, according

to the operator's judgment. The needle valve ends in a milled nut outside

the torch handle, this being the adjustment provided for the different

nozzles.

Torch Construction.—A well designed torch is so designed that the

weight distribution is best for holding it in the proper position for

welding. When a torch is grasped by its handle with the gas hose attached,

it should balance so that it does not feel appreciably heavier on one end

than on the other.

The head and nozzle may be placed so that the flame issues in a line at

right angles with the torch body, or they may be attached at an angle

convenient for the work to be done. The head set at an angle of from 120 to

170 degrees with the body is usually preferred for general work in welding,

while the cutting torch usually has its head at right angles to the body.

Removable nozzles have various size openings through them and the different

sizes are designated by numbers from 1 up. The same number does not always

indicate the same size opening in torches of different makes, nor does it

indicate a nozzle of the same capacity.

The design of the nozzle, the mixing chamber, the injector, when one is

used, and the size of the gas openings must be such that all these things

are suited to each other if a proper mixture of gas is to be secured. Parts

that are not made to work together are unsafe if used because of the danger

of a flash back of the flame into the mixing chamber and gas tubes. It is

well known that flame travels through any inflammable gas at a certain

definite rate of speed, depending on the degree of inflammability of the

gas. The easier and quicker the gas burns, the faster will the flame travel

through it.

If the gas in the nozzle and mixing chamber stood still, the flame would

immediately travel back into these parts and produce an explosion of more

or less violence. The speed with which the gases issue from the nozzle

prevent this from happening because the flame travels back through the gas

at the same speed at which the gas issues from the torch tip. Should the

velocity of the gas be greater than the speed of flame propagation through

it, it will be impossible to keep the flame at the tip, the tendency being

for a space of unburned gas to appear between tip and flame. On the other

hand, should the speed of the flame exceed the velocity with which the gas

comes from the torch there will result a flash back and explosion.

Care of Torches.—An oxy-acetylene torch is a very delicate and

sensitive device, much more so that appears on the surface. It must be

given equally as good care and attention as any other high-priced piece of

machinery if it is to be maintained in good condition for use.

It requires cleaning of the nozzles at regular intervals if used regularly.

This cleaning is accomplished with a piece of copper or brass wire run

through the opening, and never with any metal such as steel or iron that is

harder than the nozzle itself, because of the danger of changing the size

of the openings. The torch head and nozzle can often be cleaned by allowing

the oxygen to blow through at high pressure without the use of any tools.

In using a torch a deposit of carbon will gradually form inside of the

head, and this deposit will be more rapid if the operator lights the stream

of acetylene before turning any oxygen into the torch. This deposit may be

removed by running kerosene through the nozzle while it is removed from the

torch, setting fire to the kerosene and allowing oxygen to flow through

while the oil is burning.

Should a torch become clogged in the head or tubes, it may usually be

cleaned by removing the oxygen hose from the handle end, closing the

acetylene cock on the torch, placing the end of the oxygen hose over the

opening in the nozzle and turning on the oxygen under pressure to blow the

obstruction back through the passage that it has entered. By opening the

acetylene cock and closing the oxygen cock at the handle, the acetylene

passages may then be cleaned in the same way. Under no conditions should a

torch be taken apart any more than to remove the changeable nozzle, except

in the hands of those experienced in this work.

Nozzle Sizes.—The size of opening through the nozzle is determined

according to the thickness and kind of metal being handled. The following

sizes are recommended for steel:

Davis-Bournonville.   Oxweld Low

Thickness of Metal   (Medium Pressure.) Pressure

Thickness of Metal	Davis-Bournonville (Medium Pressure.) Pressure	Oxweld Low Tip No.	Head No.
1/32		Tip No. 1	Head No. 2
1/16		2	
5/64	3		
3/32	4	3	
3/8	5	4	
3/16	6	5	
¼	7	6	
5/16		7	
3/8	8	8	
½	10	9	
5/8	12	10	
¾	15	11	
Very heavy	15	12	

Cutting Torches.—Steel may be cut with a jet of oxygen at a rate of

speed greater than in any other practicable way under usual conditions. The

action consists of burning away a thin section of the metal by allowing a

stream of oxygen to flow onto it while the gas is at high pressure and the

metal at a white heat.

Image Figure 23.—Cutting Torch

The cutting torch (Figure 23) has the same characteristics as the welding

torch, but has an additional nozzle or means for temporarily using the

welding opening for the high pressure oxygen. The oxygen issues from the

opening while cutting at a pressure of from ten to 100 pounds to the square

inch.

The work is first heated to a white heat by adjusting the torch for a

welding flame. As soon as the metal reaches this temperature, the high

pressure oxygen is turned on to the white-hot portion of the steel. When

the jet of gas strikes the metal it cuts straight through, leaving a very

narrow slot and removing but little metal. Thicknesses of steel up to ten

inches can be economically handled in this way.

The oxygen nozzle is usually arranged so that it is surrounded by a number

of small jets for the heating flame. It will be seen that this arrangement

makes the heating flame always precede the oxygen jet, no matter in which

direction the torch is moved.

The torch is held firmly, either by hand or with the help of special

mechanism for guiding it in the desired path, and is steadily advanced in

the direction it is desired to extend the cut, the rate of advance being

from three inches to two feet per minute through metal from nine inches

down to one-quarter of an inch in thickness.

The following data on cutting is given by the Davis-Bournonville Company:

Thickness Inches of Steel	Cubic Feet Gases Cutting Oxygen per Foot of Cut	Heating Oxygen	Oxygen per Foot of Cut	Acetylene	Oxygen per Min.	Cost of Gas per Foot of Cut
¼	10 lbs.	4 lbs.	.40	.086	24	$ .013
½	20	4	.91	.150	15	.029
¾	30	4	1.16	.150	15	.036
1	30	4	1.45	.172		

12				.045
1 ½	30	5	2.40	.380
12				.076
2	40	5	2.96	.380
12				.093
4	50	5	9.70	.800
7				.299
6	70	6	21.09	1.50
4				.648
9	100	6	43.20	2.00
3				1.311

Acetylene-Air Torch.—A form of torch which burns the acetylene after

mixing it with atmospheric air at normal pressure rather than with the

oxygen under higher pressures has been found useful in certain pre-heating,

brazing and similar operations. This torch (Figure 24) is attached by a

rubber gas hose to any compressed acetylene tank and is regulated as to

flame size and temperature by opening or closing the tank valve more or

less.

After attaching the torch to the tank, the gas is turned on very slowly and

is lighted at the torch tip. The adjustment should cause the presence of a

greenish-white cone of flame surrounded by a larger body of burning gas,

the cone starting at the mouth of the torch.

Image Figure 24.—Acetylene-Air Torch

By opening the tank valve more, a longer and hotter flame is produced, the

length being regulated by the tank valve also. This torch will give

sufficient heat to melt steel, although not under conditions suited to

welding. Because of the excess of acetylene always present there is no

danger of oxidizing the metal being heated.

The only care required by this torch is to keep the small air passages at

the nozzle clean and free from carbon deposits. The flame should be

extinguished when not in use rather than turned low, because this low flame

rapidly deposits large quantities of soot in the burner.

CHAPTER V

OXY-ACETYLENE WELDING PRACTICE

PREPARATION OF WORK

Preheating.—The practice of heating the metal around the weld

before applying the torch flame is a desirable one for two reasons. First,

it makes the whole process more economical; second, it avoids the danger of

breakage through expansion and contraction of the work as it is heated and

as it cools.

When it is desired to join two surfaces by welding them, it is, of course,

necessary to raise the metal from the temperature of the surrounding air to

its melting point, involving an increase in temperature of from one

thousand to nearly three thousand degrees. To obtain this entire increase

of temperature with the torch flame is very wasteful of fuel and of the

operator's time. The total amount of heat necessary to put into metal is

increased by the conductivity of that metal because the heat applied at the

weld is carried to other parts of the piece being handled until the whole

mass is considerably raised in temperature. To secure this widely

distributed increase the various methods of preheating are adopted.

As to the second reason for preliminary heating. It is understood that the

metal added to the joint is molten at the time it flows into place. All the

metals used in welding contract as they cool and occupy a much smaller

space than when molten. If additional metal is run between two adjoining

surfaces which are parts of a surrounding body of cool metal, this added

metal will cool while the surfaces themselves are held stationary in the

position they originally occupied. The inevitable result is that the metal

added will crack under the strain, or, if the weld is exceptionally strong,

the main body of the work will he broken by the force of contraction. To

overcome these difficulties is the second and most important reason for

preheating and also for slow cooling following the completion of the weld.

There are many ways of securing this preheating. The work may be brought to

a red heat in the forge if it is cast iron or steel; it may he heated in

special ovens built for the purpose; it may be placed in a bed of charcoal

while suitably supported; it may be heated by gas or gasoline preheating

torches, and with very small work the outer flame of the welding torch

automatically provides means to this end.

The temperature of the parts heated should be gradually raised in all

cases, giving the entire mass of metal a chance to expand equally and to

adjust itself to the strains imposed by the preheating. After the region

around the weld has been brought to a proper temperature the opening to be

filled is exposed so that the torch flame can reach it, while the remaining

surfaces are still protected from cold air currents and from cooling

through natural radiation.

One of the commonest methods and one of the best for handling work of

rather large size is to place the piece to be welded on a bed of fire brick

and build a loose wall around it with other fire brick placed in rows, one

on top of the other, with air spaces left between adjacent bricks in each

row. The space between the brick retaining wall and the work is filled with

charcoal, which is lighted from below. The top opening of the temporary

oven is then covered with asbestos and the fire kept up until the work has

been uniformly raised in temperature to the desired point.

When much work of the same general character and size is to be handled, a

permanent oven may be constructed of fire brick, leaving a large opening

through the top and also through one side. Charcoal may be used in this

form of oven as with the temporary arrangement, or the heat may be secured

from any form of burner or torch giving a large volume of flame. In any

method employing flame to do the heating, the work itself must be protected

from the direct blast of the fire. Baffles of brick or metal should be

placed between the mouth of the torch and the nearest surface of the work

so that the flame will be deflected to either side and around the piece

being heated.

The heat should be applied to bring the point of welding to the highest

temperature desired and, except in the smallest work, the heat should

gradually shade off from this point to the other parts of the piece. In the

case of cast iron and steel the temperature at the point to be welded

should be great enough to produce a dull red heat. This will make the whole

operation much easier, because there will be no surrounding cool metal to

reduce the temperature of the molten material from the welding rod below

the point at which it will join the work. From this red heat the mass of

metal should grow cooler as the distance from the

weld becomes greater, so

that no great strain is placed upon any one part. With work of a very

irregular shape it is always best to heat the entire piece so that the

strains will be so evenly distributed that they can cause no distortion or

breakage under any conditions.

The melting point of the work which is being preheated should be kept in

mind and care exercised not to approach it too closely. Special care is

necessary with aluminum in this respect, because of its low melting

temperature and the sudden weakening and flowing without warning. Workmen

have carelessly overheated aluminum castings and, upon uncovering the piece

to make the weld, have been astonished to find that it had disappeared.

Six hundred degrees is about the safe limit for this metal. It is possible

to gauge the exact temperature of the work with a pyrometer, but when this

instrument cannot be procured, it might be well to secure a number of

"temperature cones" from a chemical or laboratory supply house. These cones

are made from material that will soften at a certain heat and in form they

are long and pointed. Placed in position on the part being heated, the

point may be watched, and when it bends over it is sure that the metal

itself has reached a temperature considerably in excess of the temperature

at which that particular cone was designed to soften.

The object in preheating the metal around the weld is to cause it to expand

sufficiently to open the crack a distance equal to the contraction when

cooling from the melting point. In the case of a crack running from the

edge of a piece into the body or of a crack wholly within the body, it is

usually satisfactory to heat the metal at each end of the opening. This

will cause the whole length of the crack to open sufficiently to receive

the molten material from the rod.

The judgment of the operator will be called upon to decide just where a

piece of metal should be heated to open the weld properly. It is often

possible to apply the preheating flame to a point some distance from the

point of work if the parts are so connected that the expansion of the

heated part will serve to draw the edges of the weld apart. Whatever part

of the work is heated to cause expansion and separation, this part must

remain hot during the entire time of welding and must then cool slowly at
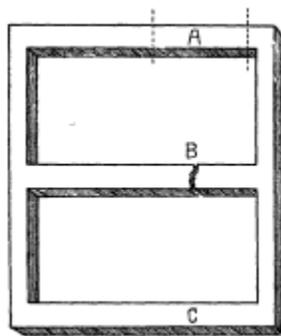
the same time as the metal in the weld cools.

Image Figure 25.—Preheating at A While Welding at B. C also May Be Heated.

An example of heating points away from the crack might be found in welding

a lattice work with one of the bars cracked through (Figure 25). If the

strips parallel and near to the broken bar are heated gradually, the work

will be so expanded that the edges of the break are drawn apart and the

weld can be successfully made. In this case, the parallel bars next to the

broken one would be heated highest, the next row not quite so hot and so on

for some distance away. If only the one row were heated, the strains set up

in the next ones would be sufficient to cause a new break to appear.
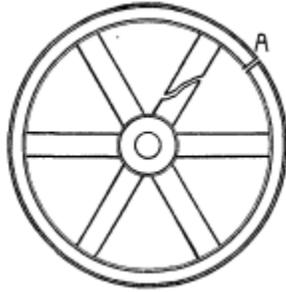
Image Figure 26.—Cutting Through the Rim of a Wheel (Cut Shown

at A)

If welding is to be done near the central portion of a large piece, the

strains will be brought to bear on the parts farthest away from the center.

Should a fly wheel spoke be broken and made ready to weld, the greatest

strain will come on the rim of the wheel. In cases like this it is often

desirable to cut through at the point of greatest strain with a saw or

cutting torch, allowing free movement while the weld is made at the

original break (Figure 26). After the inside weld is completed, the cut may

be welded without danger, for the reason that it will always be at some

point at which severe strains cannot be set up by the contraction of the

cooling metal.

Image Figure 27.—Using a Wedge While Welding

In materials that will spring to some extent without breakage, that is, in

parts that are not brittle, it may be possible to force the work out of

shape with jacks or wedges (Figure 27) in the same way that it would be

distorted by heating and expanding some portion of it as described. A

careful examination will show whether this method can be followed in such a

way as to force the edges of the break to separate. If the plan seems

feasible, the wedges may be put in place and

allowed to remain while the

weld is completed. As soon as the work is finished the wedges should be

removed so that the natural contraction can take place without damage.

It should always be remembered that it is not so much the expansion of the

work when heated as it is the contraction caused by cooling that will do

the damage. A weld may be made that, to all appearances, is perfect and it

may be perfect when completed; but if provision has not been made to allow

for the contraction that is certain to follow, there will be a breakage at

some point. It is not possible to weld the simplest shapes, other than

straight bars, without considering this difficulty and making provision to

take care of it.

The exact method to employ in preheating will always call for good judgment

on the part of the workman, and he should remember that the success or

failure of his work will depend fully as much on proper preparation as on

correct handling of the weld itself. It should be remembered that the outer

flame of the oxy-acetylene torch may be depended on for a certain amount of

preheating, as this flame gives a very large volume of heat, but a heat

that is not so intense nor so localized as the welding flame itself. The

heat of this part of the flame should be fully utilized during the

operation of melting the metal and it should be so directed, when possible,

that it will bring the parts next to be joined to as high a temperature as

possible.

When the work has been brought to the desired temperature, all parts except

the break and the surface immediately surrounding it on both sides should

be covered with heavy sheet asbestos. This protecting cover should remain

in place throughout the operation and should only be moved a distance

sufficient to allow the torch flame to travel in the path of the weld. The

use of asbestos in this way serves a twofold purpose. It retains the heat

in the work and prevents the breakage that would follow if a draught of air

were to strike the heated metal, and it also prevents such a radiation of

heat through the surrounding air as would make it almost impossible for the

operator to perform his work, especially in the case of large and heavy

castings when the amount of heat utilized is large.

Cleaning and Champfering.—A perfect weld can never be made unless

the surfaces to be joined have been properly prepared to receive the new

metal.

All spoiled, burned, corroded and rough particles must positively be

removed with chisel and hammer and with a free application of emery cloth

and wire brush. The metal exposed to the welding flame should be perfectly

clean and bright all over, or else the additional material will not unite,

but will only stick at best.

Image Figure 28.—Tapering the Opening Formed by a Break

Following the cleaning it is always necessary to bevel, or champfer, the

edges except in the thinnest sheet metal. To make a weld that will hold,

the metal must be made into one piece, without holes or unfilled portions

at any point, and must be solid from inside to outside. This can only be

accomplished by starting the addition of metal at one point and gradually

building it up until the outside, or top, is

reached. With comparatively

thin plates the molten metal may be started from the side farthest from the

operator and brought through, but with thicker sections the addition is

started in the middle and brought flush with one side and then with the

other.

It will readily be seen that the molten material cannot be depended upon to

flow between the tightly closed surfaces of a crack in a way that can be at

all sure to make a true weld. It will be necessary for the operator to

reach to the farthest side with the flame and welding rod, and to start the

new surfaces there. To allow this, the edges that are to be joined are

beveled from one side to the other (Figure 28), so that when placed

together in approximately the position they are to occupy they will leave a

grooved channel between them with its sides at an angle with each other

sufficient in size to allow access to every point of each surface.

Image Figure 29.—Beveling for Thin Work

Image Figure 30.—Beveling for Thick Work

With work less than one-fourth inch thick, this angle should be forty-five

degrees on each piece (Figure 29), so that when they are placed together

the extreme edges will meet at the bottom of a groove whose sides are

square, or at right angles, to each other. This beveling should be done so

that only a thin edge is left where the two parts come together, just

enough points in contact to make the alignment easy to hold. With work of a

thickness greater than a quarter of an inch, the angle of bevel on each

piece may be sixty degrees (Figure 30), so that

when placed together the

angle included between the sloping sides will also be sixty degrees. If the

plate is less than one-eighth of an inch thick the beveling is not

necessary, as the edges may be melted all the way through without danger of

leaving blowholes at any point.

Image Figure 31.—Beveling Both Sides of a Thick Piece

Image Figure 32.—Beveling the End of a Pipe

This beveling may be done in any convenient way. A chisel is usually most

satisfactory and also quickest. Small sections may be handled by filing,

while metal that is too hard to cut in either of these ways may be shaped

on the emery wheel. It is not necessary that the edges be perfectly

finished and absolutely smooth, but they should be of regular outline and

should always taper off to a thin edge so that when the flame is first

applied it can be seen issuing from the far side of the crack. If the work

is quite thick and is of a shape that will allow it to be turned over, the

bevel may be brought from both sides (Figure 31), so that there will be two

grooves, one on each surface of the work. After completing the weld on one

side, the piece is reversed and finished on the other side. Figure 32 shows

the proper beveling for welding pipe. Figure 33 shows how sheet metal may

be flanged for welding.

Welding should not be attempted with the edges separated in place of

beveled, because it will be found impossible to build up a solid web of new

metal from one side clear through to the other by this method. The flame

cannot reach the surfaces to make them molten while receiving new material

from the rod, and if the flame does not reach them it will only serve to

cause a few drops of the metal to join and will surely cause a weak and

defective weld.

Image Figure 33.—Flanging Sheet Metal for Welding

Supporting Work.—During the operation of welding it is necessary

that the work be well supported in the position it should occupy. This may

be done with fire brick placed under the pieces in the correct position,

or, better still, with some form of clamp. The edges of the crack should

touch each other at the point where welding is to start and from there

should gradually separate at the rate of about one-fourth inch to the foot.

This is done so that the cooling of the molten metal as it is added will

draw the edges together by its contraction.

Care must be used to see that the work is supported so that it will

maintain the same relative position between the parts as must be present

when the work is finished. In this connection it must be remembered that

the expansion of the metal when heated may be great enough to cause serious

distortion and to provide against this is one of the difficulties to be

overcome.

Perfect alignment should be secured between the separate parts that are to

be joined and the two edges must be held up so that they will be in the

same plane while welding is carried out. If, by any chance, one drops

below the other while molten metal is being added, the whole job may have

to be undone and done over again. One precaution that is necessary is that

of making sure that the clamping or supporting does not in itself pull the

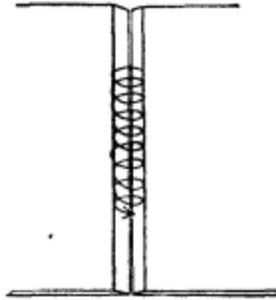work out of shape while melted.

TORCH PRACTICE

Image Figure 34.—Rotary Movement of Torch in Welding

The weld is made by bringing the tip of the welding flame to the edges of

the metals to be joined. The torch should be held in the right hand and

moved slowly along the crack with a rotating motion, traveling in small

circles (Figure 34), so that the Welding flame touches first on one side of

the crack and then on the other. On large work the motion may be simply

back and forth across the crack, advancing regularly as the metal unites.

It is usually best to weld toward the operator rather than from him,

although this rule is governed by circumstances. The head of the torch

should be inclined at an angle of about 60 degrees to the surface of the

work. The torch handle should extend in the same line with the break

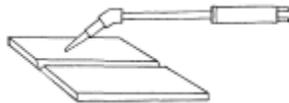(Figure 35) and not across it, except when welding very light plates.

Image Figure 35.—Torch Held in Line with the Break

If the metal is 1/16 inch or less in thickness it is only necessary to

circle along the crack, the metal itself furnishing enough material to

complete the weld without additions. Heat both sides evenly until they flow

together.

Material thicker than the above requires the addition of more metal of the

same or different kind from the welding rod, this rod being held by the

left hand. The proper size rod for cast iron is one having a diameter equal

to the thickness of metal being welded up to a one-half inch rod, which is

the largest used. For steel the rod should be one-half the thickness of the

metal being joined up to one-fourth inch rod. As a general rule, better

results will be obtained by the use of smaller rods, the very small sizes

being twisted together to furnish enough material while retaining the free
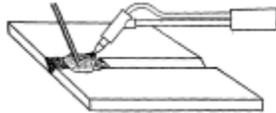
melting qualities.

Image Figure 36.—The Welding Rod Should Be Held in the Molten

Metal

The tip of the rod must at all times be held in contact with the pieces

being welded and the flame must be so directed that the two sides of the

crack and the end of the rod are melted at the same time (Figure 36).

Before anything is added from the rod, the sides of the crack are melted

down sufficiently to fill the bottom of the groove and join the two sides.

Afterward, as metal comes from the rod in filling the crack, the flame is

circled along the joint being made, the rod always following the flame.

Image Figure 37.—Welding Pieces of Unequal Thickness

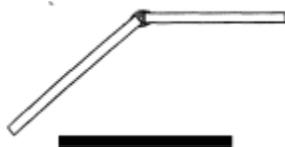Figure 37 illustrates the welding of pieces of unequal thickness.

Figure 38 illustrates welding at an angle.

The molten metal may be directed as to where it should go by the tip of the

welding flame, which has considerable force, but care must be taken not to

blow melted metal on to cooler surfaces which it cannot join. If, while

welding, a spot appears which does not unite with the weld, it may be

handled by heating all around it to a white heat and then immediately

welding the bad place.

Image Figure 38.—Welding at an Angle

Never stop in the middle of a weld, as it is extremely difficult to

continue smoothly when resuming work.

The Flame.—The welding flame must have exactly the right

proportions of each gas. If there is too much oxygen, the metal will be

burned or oxidized; the presence of too much acetylene carbonizes the

metal; that is to say, it adds carbon and makes the work harder. Just the

right mixture will neither burn nor carbonize and is said to be a "neutral"

flame. The neutral flame, if of the correct size for the work, reduces the

metal to a melted condition, not too fluid, and for a width about the same

as the thickness of the metal being welded.

When ready to light the torch, after attaching the right tip or head as

directed in accordance with the thickness of metal to be handled, it will

be necessary to regulate the pressure of gases to secure the neutral flame.

The oxygen will have a pressure of from 2 to 20 pounds, according to the

nozzle used. The acetylene will have much less. Even with the compressed

gas, the pressure should never exceed 10 pounds for the largest work, and

it will usually be from 4 to 6. In low pressure systems, the acetylene will

be received at generator pressure. It should first be seen that the

hand-screws on the regulators are turned way out

so that the springs are

free from any tension. It will do no harm if these screws are turned back

until they come out of the threads. This must be done with both oxygen and

acetylene regulators.

Next, open the valve from the generator, or on the acetylene tank, and

carefully note whether there is any odor of escaping gas. Any leakage of

this gas must be stopped before going on with the work.

The hand wheel controlling the oxygen cylinder valve should now be turned

very slowly to the left as far as it will go, which opens the valve, and

it should be borne in mind the pressure that is being released. Turn in the

hand screw on the oxygen regulator until the small pressure gauge shows a

reading according to the requirements of the nozzle being used. This oxygen

regulator adjustment should be made with the cock on the torch open, and

after the regulator is thus adjusted the torch cock may be closed.

Open the acetylene cock on the torch and screw in on the acetylene

regulator hand-screw until gas commences to come through the torch. Light

this flow of acetylene and adjust the regulator screw to the pressure

desired, or, if there is no gauge, so that there is a good full flame. With

the pressure of acetylene controlled by the type of generator it will only

be necessary to open the torch cock.

With the acetylene burning, slowly open the oxygen cock on the torch and

allow this gas to join the flame. The flame will turn intensely bright and

then blue white. There will be an outer flame from four to eight inches

long and from one to three inches thick. Inside of this flame will be two

more rather distinctly defined flames. The inner one at the torch tip is

very small, and the intermediate one is long and pointed. The oxygen should

be turned on until the two inner flames unite into one blue-white cone from

one-fourth to one-half inch long and one-eighth to one-fourth inch in

diameter. If this single, clearly defined cone does not appear when the

oxygen torch cock has been fully opened, turn off some of the acetylene

until it does appear.

If too much oxygen is added to the flame, there will still be the central

blue-white cone, but it will be smaller and more or less ragged around the

edges (Figure 39). When there is just enough oxygen to make the single

cone, and when, by turning on more acetylene or by turning off oxygen, two

cones are caused to appear, the flame is neutral (Figure 40), and the small

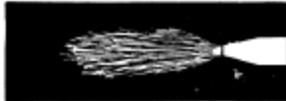blue-white cone is called the welding flame.

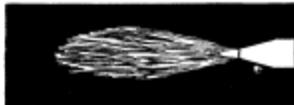Image Figure 39.—Oxidizing Flame—Too Much Oxygen

Image Figure 40.—Neutral Flame

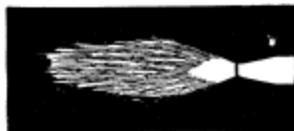Image Figure 41.—Reducing Flame—Showing an Excess of Acetylene

While welding, test the correctness of the flame adjustment occasionally by

turning on more acetylene or by turning off some oxygen until two flames or

cones appear. Then regulate as before to secure the single distinct cone.

Too much oxygen is not usually so harmful as too much acetylene, except

with aluminum. (See Figure 41.) An excessive

amount of sparks coming from

the weld denotes that there is too much oxygen in the flame. Should the

opening in the tip become partly clogged, it will be difficult to secure a

neutral flame and the tip should be cleaned with a brass or copper

wire—never with iron or steel tools or wire of any kind. While the torch

is doing its work, the tip may become excessively hot due to the heat

radiated from the molten metal. The tip may be cooled by turning off the

acetylene and dipping in water with a slight flow of oxygen through the

nozzle to prevent water finding its way into the mixing chamber.

The regulators for cutting are similar to those for welding, except that

higher pressures may be handled, and they are fitted with gauges reading up

to 200 or 250 pounds pressure.

In welding metals which conduct the heat very rapidly it is necessary to

use a much larger nozzle and flame than for metals which have not this

property. This peculiarity is found to the greatest extent in copper,

aluminum and brass.

Should a hole be blown through the work, it may be closed by withdrawing

the flame for a few seconds and then commencing to build additional metal

around the edges, working all the way around and finally closing the small

opening left at the center with a drop or two from the welding rod.

WELDING VARIOUS METALS

Because of the varying melting points, rates of expansion and contraction,

and other peculiarities of different metals, it is necessary to give

detailed consideration to the most important ones.

Characteristics of Metals.—The welder should thoroughly understand

the peculiarities of the various metals with which he has to deal. The

metals and their alloys are described under this heading in the first

chapter of this book and a tabulated list of the most important points

relating to each metal will be found at the end of the present chapter.

All this information should be noted by the operator of a welding

installation before commencing actual work.

Because of the nature of welding, the melting point of a metal is of great

importance. A metal melting at a low temperature should have more careful

treatment to avoid undesired flow than one which melts at a temperature

which is relatively high. When two dissimilar metals are to be joined, the

one which melts at the higher temperature must be acted upon by the flame

first and when it is in a molten condition the heat contained in it will in

many cases be sufficient to cause fusion of the lower melting metal and

allow them to unite without playing the flame on the lower metal to any

great extent.

The heat conductivity bears a very important relation to welding, inasmuch

as a metal with a high rate of conductance requires more protection from

cooling air currents and heat radiation than one not having this quality to

such a marked extent. A metal which conducts heat rapidly will require a

larger volume of flame, a larger nozzle, than otherwise, this being

necessary to supply the additional heat taken away from the welding point

by this conductance.

The relative rates of expansion of the various metals under heat should be

understood in order that parts made from such material may have proper

preparation to compensate for this expansion and contraction. Parts made

from metals having widely varying rates of expansion must have special

treatment to allow for this quality, otherwise breakage is sure to occur.

Cast Iron.—All spoiled metal should he cut away and if the work is

more than one-eighth inch in thickness the sides of the crack should be

beveled to a 45 degree angle, leaving a number of points touching at the

bottom of the bevel so that the work may be joined in its original

relation.

The entire piece should be preheated in a bricked-up oven or with charcoal

placed on the forge, when size does not warrant building a temporary oven.

The entire piece should be slowly heated and the portion immediately

surrounding the weld should be brought to a dull red. Care should be used

that the heat does not warp the metal through application to one part more

than the others. After welding, the work should be slowly cooled by

covering with ashes, slaked lime, asbestos fiber or some other

non-conductor of heat. These precautions are absolutely essential in the

case of cast iron.

A neutral flame, from a nozzle proportioned to the thickness of the work,

should be held with the point of the blue-white cone about one-eighth inch

from the surface of the iron.

A cast iron rod of correct diameter, usually made with an excess of

silicon, is used by keeping its end in contact with the molten metal and

flowing it into the puddle formed at the point of fusion. Metal should be

added so that the weld stands about one-eighth inch above the surrounding

surface of the work.

Various forms of flux may be used and they are applied by dipping the end

of the welding rod into the powder at intervals.

These powders may contain

borax or salt, and to prevent a hard, brittle weld, graphite or

ferro-silicon may be added. Flux should be added only after the iron is

molten and as little as possible should be used. No flux should be used

just before completion of the work.

The welding flame should be played on the work around the crack and

gradually brought to bear on the work. The bottom of the bevel should be

joined first and it will be noted that the cast iron tends to run toward

the flame, but does not stick together easily. A hard and porous weld

should be carefully guarded against, as described above, and upon

completion of the work the welded surface should be scraped with a file,

while still red hot, in order to remove the surface scale.

Malleable Iron.—This material should be beveled in the same way

that cast iron is handled, and preheating and slow cooling are equally

desirable. The flame used is the same as for cast iron and so is the flux.

The welding rod may be of cast iron, although better results are secured

with Norway iron wire or else a mild steel wire wrapped with a coil of

copper wire.

It will be understood that malleable iron turns to ordinary cast iron when

melted and cooled. Welds in malleable iron are usually far from

satisfactory and a better joint is secured by brazing the edges together

with bronze. The edges to be joined are brought to a heat just a little

below the point at which they will flow and the opening is then

quickly-filled from a rod of Tobin bronze or manganese bronze, a brass or

bronze flux being used in this work.

Wrought Iron or Semi-Steel.—This metal should be

beveled and heated

in the same way as described for cast iron. The flame should be neutral, of

the same size as for steel, and used with the tip of the blue-white cone

just touching the work. The welding rod should be of mild steel, or, if

wrought iron is to be welded to steel, a cast iron rod may be used. A cast

iron flux is well suited for this work. It should be noted that wrought

iron turns to ordinary cast iron if kept heated for any length of time.

Steel.—Steel should be beveled if more than one-eighth inch in

thickness. It requires only a local preheating around the point to be

welded. The welding flame should be absolutely neutral, without excess of

either gas. If the metal is one-sixteenth inch or less in thickness, the

tip of the blue-white cone must be held a short distance from the surface

of the work; in all other cases the tip of this cone is touched to the

metal being welded.

The welding rod may be of mild, low carbon steel or of Norway iron. Nickel

steel rods may be used for parts requiring great strength, but vanadium

alloys are very difficult to handle. A very satisfactory rod is made by

twisting together two wires of the required material. The rod must be kept

constantly in contact with the work and should not be added until the edges

are thoroughly melted. The flux may or may not be used. If one is wanted,

it may be made from three parts iron filings, six parts borax and one part

sal ammoniac.

It will be noticed that the steel runs from the flame, but tends to hold

together. Should foaming commence in the molten metal, it shows an excess

of oxygen and that the metal is being burned.

High carbon steels are very difficult to handle.

It is claimed that a drop
or two of copper added to the weld will assist the flow, but will also
harden the work. An excess of oxygen reduces the amount of carbon and
softens the steel, while an excess of acetylene increases the proportion of
carbon and hardens the metal. High speed steels may sometimes be welded if
first coated with semi-steel before welding.

Aluminum.—This is the most difficult of the commonly found metals
to weld. This is caused by its high rate of expansion and contraction and
its liability to melt and fall away from under the flame. The aluminum
seems to melt on the inside first, and, without previous warning, a portion
of the work will simply vanish from in front of the operator's eyes. The
metal tends to run from the flame and separate at the same time. To keep
the metal in shape and free from oxide, it is worked or puddled while in a
plastic condition by an iron rod which has been flattened at one end.
Several of these rods should be at hand and may be kept in a jar of salt
water while not being used. These rods must not become coated with aluminum
and they must not get red hot while in the weld.
The surfaces to be joined, together with the adjacent parts, should be
cleaned thoroughly and then washed with a 25 per cent solution of nitric
acid in hot water, used on a swab. The parts should then be rinsed in clean
water and dried with sawdust. It is also well to make temporary fire clay
moulds back of the parts to be heated, so that the metal may be flowed into
place and allowed to cool without danger of breakage.
Aluminum must invariably be preheated to about 600 degrees, and the whole
piece being handled should be well covered with sheet asbestos to prevent

excessive heat radiation.

The flame is formed with an excess of acetylene such that the second cone

extends about an inch, or slightly more, beyond the small blue-white point.

The torch should be held so that the end of this second cone is in contact

with the work, the small cone ordinarily used being kept an inch or an inch

and a half from the surface of the work.

Welding rods of special aluminum are used and must be handled with their

end submerged in the molten metal of the weld at all times.

When aluminum is melted it forms alumina, an oxide of the metal. This

alumina surrounds small masses of the metal, and as it does not melt at

temperatures below 5000 degrees (while aluminum melts at about 1200), it

prevents a weld from being made. The formation of this oxide is retarded

and the oxide itself is dissolved by a suitable flux, which usually

contains phosphorus to break down the alumina.

Copper.—The whole piece should be preheated and kept well covered

while welding. The flame must be much larger than for the same thickness of

steel and neutral in character. A slight excess of acetylene would be

preferable to an excess of oxygen, and in all cases the molten metal should

be kept enveloped with the flame. The welding rod is of copper which

contains phosphorus; and a flux, also containing phosphorus, should be

spread for about an inch each side of the joint. These assist in preventing

oxidation, which is sure to occur with heated copper.

Copper breaks very easily at a heat slightly under the welding temperature

and after cooling it is simply cast copper in all cases.

Brass and Bronze.—It is necessary to preheat these metals, although

not to a very high temperature. They must be kept well covered at all times

to prevent undue radiation. The flame should be produced with a nozzle one

size larger than for the same thickness of steel and the small blue-white

cone should be held from one-fourth to one-half inch above the surface of

the work. The flame should be neutral in character.

A rod or wire of soft brass containing a large percentage of zinc is

suitable for adding to brass, while copper requires the use of copper or

manganese bronze rods. Special flux or borax may be used to assist the

flow.

The emission of white smoke indicates that the zinc contained in these

alloys is being burned away and the heat should immediately be turned away

or reduced. The fumes from brass and bronze welding are very poisonous and

should not be breathed.

RESTORATION OF STEEL

The result of the high heat to which the steel has been subjected is that

it is weakened and of a different character than before welding. The

operator may avoid this as much as possible by first playing the outer

flame of the torch all over the surfaces of the work just completed until

these faces are all of uniform color, after which the metal should be well

covered with asbestos and allowed to cool without being disturbed. If a

temporary heating oven has been employed, the work and oven should be

allowed to cool together while protected with the sheet asbestos. If the

outside air strikes the freshly welded work, even for a moment, the result

will be breakage.

A weld in steel will always leave the metal with a coarse grain and with

all the characteristics of rather low grade cast steel. As previously

mentioned in another chapter, the larger the grain size in steel the weaker

the metal will be, and it is the purpose of the good workman to avoid, as

far as possible, this weakening.

The structure of the metal in one piece of steel will differ according to

the heat that it has under gone. The parts of the work that have been at

the melting point will, therefore, have the largest grain size and the

least strength. Those parts that have not suffered any great rise in

temperature will be practically unaffected, and all the parts between these

two extremes will be weaker or stronger according to their distance from

the weld itself. To restore the steel so that it will have the best grain

size, the operator may resort to either of two methods: (1) The grain may

be improved by forging. That means that the metal added to the weld and the

surfaces that have been at the welding heat are hammered much as a

blacksmith would hammer his finished work to give it greater strength. The

hammering should continue from the time the metal first starts to cool

until it has reached the temperature at which the grain size is best for

strength. This temperature will vary somewhat with the composition of the

metal being handled, but in a general way, it may be stated that the

hammering should continue without intermission from the time the flame is

removed from the weld until the steel just begins to show attraction for a

magnet presented to it. This temperature of magnetic attraction will always

be low enough and the hammering should be immediately discontinued at this

point. (2) A method that is more satisfactory, although harder to apply, is

that of reheating the steel to a certain

temperature throughout its whole

mass where the heat has had any effect, and then allowing slow and even

cooling from this temperature. The grain size is affected by the

temperature at which the reheating is stopped, and not by the cooling, yet

the cooling should be slow enough to avoid strains caused by uneven

contraction.

After the weld has been completed the steel must be allowed to cool until

below 1200° Fahrenheit. The next step is to heat the work slowly until all

those parts to be restored have reached a temperature at which the magnet

just ceases to be attracted. While the very best temperature will vary

according to the nature and hardness of the steel being handled, it will be

safe to carry the heating to the point indicated by the magnet in the

absence of suitable means of measuring accurately these high temperatures.

In using a magnet for testing, it will be most satisfactory if it is an

electromagnet and not of the permanent type. The electric current may be

secured from any small battery and will be the means of making sure of the

test. The permanent magnet will quickly lose its power of attraction under

the combined action of the heat and the jarring to which it will be

subjected.

In reheating the work it is necessary to make sure that no part reaches a

temperature above that desired for best grain size and also to see that all

parts are brought to this temperature. Here enters the greatest difficulty

in restoring the metal. The heating may be done so slowly that no part of

the work on the outside reaches too high a temperature and then keeps the

outside at this heat until the entire mass is at the same temperature. A

less desirable way is to heat the outside higher than this temperature and

allow the conductivity of the metal to distribute the excess to the inside.

The most satisfactory method, where it can be employed, is to make use of a

bath of some molten metal or some chemical mixture that can be kept at the

exact heat necessary by means of gas fires that admit of close regulation.

The temperature of these baths may be maintained at a constant point by

watching a pyrometer, and the finished work may be allowed to remain in the

bath until all parts have reached the desired temperature.

WELDING INFORMATION

The following tables include much of the information that the operator must

use continually to handle the various metals successfully. The temperature

scales are given for convenience only. The composition of various alloys

will give an idea of the difficulties to be contended with by consulting

the information on welding various metals. The remaining tables are of

self-evident value in this work.

TEMPERATURE SCALES

Centigrade	Fahrenheit	Centigrade	Fahrenheit
200°	392°	1000°	1832°
225°	437°	1050°	1922°
250°	482°	1100°	2012°
275°	527°	1150°	2102°
300°	572°	1200°	2192°
325°	617°	1250°	2282°
350°	662°	1300°	2372°
375°	707°	1350°	2462°
400°	752°	1400°	2552°
425°	797°	1450°	2642°
450°	842°	1500°	2732°
475°	887°	1550°	2822°
500°	932°	1600°	2912°

525°	977°	1650°	3002°
550°	1022°	1700°	3092°
575°	1067°	1750°	3182°
600°	1112°	1800°	3272°
625°	1157°	1850°	3362°
650°	1202°	1900°	3452°
675°	1247°	2000°	3632°
700°	1292°	2050°	3722°
725°	1337°	2100°	3812°
750°	1382°	2150°	3902°
775°	1427°	2200°	3992°
800°	1472°	2250°	4082°
825°	1517°	2300°	4172°
850°	1562°	2350°	4262°
875°	1607°	2400°	4352°
900°	1652°	2450°	4442°
925°	1697°	2500°	4532°
950°	1742°	2550°	4622°
975°	1787°	2600°	4712°

METAL ALLOYS
(Society of Automobile Engineers)
Babbitt—
Tin........................... 84.00%
Antimony..................... 9.00%
Copper....................... 7.00%

Brass, White—
Copper...................... 3.00% to 6.00%
Tin (minimum) 65.00%
Zinc........................ 28.00% to 30.00%
Brass, Red Cast—
Copper....................... 85.00%
Tin.......................... 5.00%
Lead......................... 5.00%
Zinc......................... 5.00%

Brass, Yellow—
Copper...................... 62.00% to 65.00%
Lead........................ 2.00% to 4.00%

```
Zinc........................ 36.00% to 31.00%
Bronze, Hard—
Copper...................... 87.00% to 88.00%
Tin.........................  9.50% to 10.50%
Zinc........................  1.50% to  2.50%
Bronze, Phosphor—
Copper......................          80.00%
Tin.........................          10.00%
Lead........................          10.00%
Phosphorus..................   .50% to   .25%


Bronze, Manganese—
Copper (approximate) .........         60.00%
Zinc (approximate) ...........         40.00%
Manganese (variable) .........         small


Bronze, Gear—
Copper...................... 88.00% to 89.00%
Tin......................... 11.00% to 12.00%
Aluminum Alloys—
Aluminum   Copper   Zinc   Manganese
No. 1.. 90.00%    8.5-7.0%
No. 2.. 80.00%    2.0-3.0%  15%  Not over 0.40%
No. 3.. 65.00%             35.0%


Cast Iron—
Gray Iron      Malleable
Total carbon........3.0 to 3.5%
Combined carbon.....0.4 to 0.7%
Manganese...........0.4 to 0.7%    0.3 to 0.7%
Phosphorus..........0.6 to 1.0%  Not over 0.2%
Sulphur..........Not over 0.1%  Not over 0.6%
Silicon............1.75 to 2.25% Not over 1.0%
Carbon Steel (10 Point)--
Carbon......................   .05% to .15%
Manganese...................   .30% to .60%
Phosphorus (maximum)..........         .045%
Sulphur (maximum)............          .05%
(20 Point)--
Carbon......................   .15% to .25%
```

```
Manganese.....................    .30% to .60%
Phosphorus (maximum)..........         .045%
Sulphur (maximum).............         .05%
(35 Point)--
Manganese.....................    .50% to .80%
Carbon........................    .30% to .40%
Phosphorus (maximum)..........         .05%
Sulphur (maximum).............         .05%
(95 Point)--
Carbon........................    .90% to 1.05%
Manganese.....................    .25% to  .50%
Phosphorus (maximum)..........         .04%
Sulphur (maximum).............         .05%
```

HEATING POWER OF FUEL GASES

(In B.T.U. per Cubic Foot.)

```
Acetylene....... 1498.99   Ethylene....... 1562.9
Hydrogen.......  291.96   Methane........  953.6
Alcohol........ 1501.76
```

MELTING POINTS OF METALS

```
Platinum...................3200°
Iron, wrought..............2900°
malleable.................2500°
cast......................2400°
pure......................2760°
Steel, mild................2700°
Medium....................2600°
Hard......................2500°
Copper.....................1950°
Brass......................1800°
Silver.....................1750°
Bronze.....................1700°
Aluminum...................1175°
Antimony...................1150°
Zinc....................... 800°
Lead....................... 620°
Babbitt.................500-700°
Solder..................500-575°
Tin....................... 450°
```

NOTE.—These melting points are for average compositions and conditions.

The exact proportion of elements entering into the metals affects their

melting points one way or the other in practice.

TENSILE STRENGTH OF METALS

Alloy steels can be made with tensile strengths as high as 300,000 pounds

per square inch. Some carbon steels are given below according to "points":

Pounds per Square Inch

Steel, 10 point	50,000 to 65,000
20 point	60,000 to 80,000
40 point	70,000 to 100,000
60 point	90,000 to 120,000
Iron, Cast	13,000 to 30,000
Wrought	40,000 to 60,000
Malleable	25,000 to 45,000
Copper	24,000 to 50,000
Bronze	30,000 to 60,000
Brass, Cast	12,000 to 18,000
Rolled	30,000 to 40,000
Wire	60,000 to 75,000
Aluminum	12,000 to 23,000
Zinc	5,000 to 15,000
Tin	3,000 to 5,000
Lead	1,500 to 2,500

CONDUCTIVITY OF METALS

(Based on the Value of Silver as 100)

	Heat	Electricity
Silver	100	100
Copper	74	99
Aluminum	38	63
Brass	23	22
Zinc	19	29
Tin	14	15
Wrought Iron	12	16
Steel	11.5	12
Cast Iron	11	12
Bronze	9	7
Lead	8	9

WEIGHT OF METALS

(Per Cubic Inch)

Pounds		Pounds	
Lead.............	.410	Wrought Iron.....	.278
Copper..........	.320	Tin..............	.263
Bronze..........	.313	Cast Iron........	.260
Brass...........	.300	Zinc.............	.258
Steel...........	.283	Aluminum.........	.093

EXPANSION OF METALS

(Measured in Thousandths of an Inch per Foot of Length When Raised 1000 Degrees in Temperature)

Inch		Inch	
Lead.............	.188	Brass............	.115
Zinc.............	.168	Copper...........	.106
Aluminum........	.148	Steel............	.083
Silver..........	.129	Wrought Iron.....	.078
Bronze..........	.118	Cast Iron........	.068

CHAPTER VI
ELECTRIC WELDING

RESISTANCE METHOD

Two distinct forms of electric welding apparatus are in use, one producing

heat by the resistance of the metal being treated to the passage of

electric current, the other using the heat of the electric arc.

The resistance process is of the greatest use in manufacturing lines where

there is a large quantity of one kind of work to do, many thousand pieces

of one kind, for instance. The arc method may be applied in practically any

case where any other form of weld may be made. The resistance process will

be described first.

It is a well known fact that a poor conductor of electricity will offer so

much resistance to the flow of electricity that it will heat. Copper is a

good conductor, and a bar of iron, a comparatively poor conductor, when

placed between heavy copper conductors of a welder, becomes heated in

attempting to carry the large volume of current. The degree of heat depends

on the amount of current and the resistance of the conductor.

In an electric circuit the ends of two pieces of metal brought together

form the point of greatest resistance in the electric circuit, and the

abutting ends instantly begin to heat. The hotter this metal becomes, the

greater the resistance to the flow of current; consequently, as the edges

of the abutting ends heat, the current is forced into the adjacent cooler

parts, until there is a uniform heat throughout the entire mass. The heat

is first developed in the interior of the metal so that it is welded there

as perfectly as at the surface.
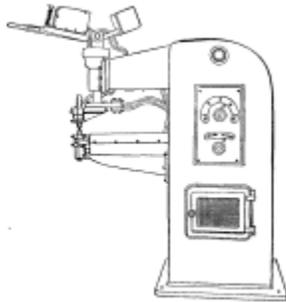
Image Figure 42.—Spot Welding Machine

The electric welder (Figure 42) is built to hold the parts to be joined

between two heavy copper dies or contacts. A current of three to five

volts, but of very great volume (amperage), is allowed to pass across

these dies, and in going through the metal to be welded, heats the edges

to a welding temperature. It may be explained that the voltage of an

electric current measures the pressure or force with which it is being sent

through the circuit and has nothing to do with the quantity or volume

passing. Amperes measure the rate at which the current is passing through

the circuit and consequently give a measure of the quantity which passes in

any given time. Volts correspond to water pressure measured by pounds to

the square inch; amperes represent the flow in gallons per minute. The low

voltage used avoids all danger to the operator, this pressure not being

sufficient to be felt even with the hands resting on the copper contacts.

Current is supplied to the welding machine at a higher voltage and lower

amperage than is actually used between the dies, the low voltage and high

amperage being produced by a transformer incorporated in the machine

itself. By means of windings of suitable size wire, the outside current may

be received at voltages ranging from 110 to 550 and converted to the low

pressure needed.

The source of current for the resistance welder must be alternating, that

is, the current must first be negative in value and then positive, passing

from one extreme to the other at rates varying from 25 to 133 times a

second. This form is known as alternating current, as opposed to direct

current, in which there is no changing of positive and negative.

The current must also be what is known as single phase, that is, a current

which rises from zero in value to the highest point as a positive current

and then recedes to zero before rising to the highest point of negative

value. Two-phase of three-phase currents would give two or three positive

impulses during this time.

As long as the current is single phase alternating, the voltage and cycles

(number of alternations per second) may be anything convenient. Various

voltages and cycles are taken care of by specifying all these points when

designing the transformer which is to handle the current.

Direct current is not used because there is no way of reducing the voltage

conveniently without placing resistance wires in the circuit and this uses

power without producing useful work. Direct current may be changed to

alternating by having a direct current motor running an alternating current

dynamo, or the change may be made by a rotary converter, although this last

method is not so satisfactory as the first.

The voltage used in welding being so low to start with, it is absolutely

necessary that it be maintained at the correct point. If the source of

current supply is not of ample capacity for the welder being used, it will

be very hard to avoid a fall of voltage when the current is forced to pass

through the high resistance of the weld. The current voltage for various

work is calculated accurately, and the efficiency of the outfit depends to

a great extent on the voltage being constant.

A simple test for fall of voltage is made by connecting an incandescent

electric lamp across the supply lines at some point near the welder. The

lamp should burn with the same brilliancy when the weld is being made as at

any other time. If the lamp burns dim at any time, it indicates a drop in

voltage, and this condition should be corrected.

The dynamo furnishing the alternating current may be in the same building

with the welder and operated from a direct current motor, as mentioned

above, or operated from any convenient shafting or source of power. When

the dynamo is a part of the welding plant it should be placed as close to

the welding machine as possible, because the length of the wire used

affects the voltage appreciably.

In order to hold the voltage constant, the Toledo

Electric Welder Company

has devised connections which include a rheostat to insert a variable

resistance in the field windings of the dynamo so that the voltage may be

increased by cutting this resistance out at the proper time. An auxiliary

switch is connected to the welder switch so that both switches act

together. When the welder switch is closed in making a weld, that portion

of the rheostat resistance between two arms determining the voltage is

short circuited. This lowers the resistance and the field magnets of the

dynamo are made stronger so that additional voltage is provided to care for

the resistance in the metal being heated.

A typical machine is shown in the accompanying cut (Figure 43). On top of

the welder are two jaws for holding the ends of the pieces to be welded.

The lower part of the jaws is rigid while the top is brought down on top of

the work, acting as a clamp. These jaws carry the copper dies through which

the current enters the work being handled. After the work is clamped

between the jaws, the upper set is forced closer to the lower set by a long

compression lever. The current being turned on with the surfaces of the

work in contact, they immediately heat to the welding point when added

pressure on the lever forces them together and completes the weld.
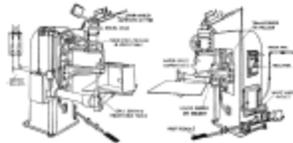
Image Figure 43--Operating Parts of a Toledo Spot Welder
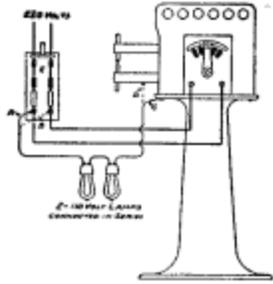
Image Figure 43a.—Method of Testing Electric Welder

Image Figure 44.—Detail of Water-Cooled Spot Welding Head

The transformer is carried in the base of the machine and on the left-hand

side is a regulator for controlling the voltage for various kinds of work.

The clamps are applied by treadles convenient to the foot of the operator.

A treadle is provided which instantly releases both jaws upon the

completion of the weld. One or both of the copper dies may be cooled by a

stream of water circulating through it from the city water mains

(Figure 44). The regulator and switch give the operator control of the

heat, anything from a dull red to the melting point being easily obtained

by movement of the lever (figure 45).
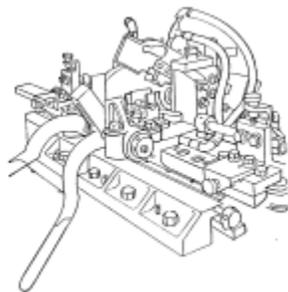
Image Figure 45.—Welding Head of a Water-Cooled Welder

Welding.—It is not necessary to give the metal to be welded any

special preparation, although when very rusty or covered with scale, the

rust and scale should be removed sufficiently to allow good contact of

clean metal on the copper dies. The cleaner and better the stock, the less

current it takes, and there is less wear on the dies. The dies should be

kept firm and tight in their holders to make a good contact. All bolts and

nuts fastening the electrical contacts should be clean and tight at all

times.

The scale may be removed from forgings by immersing them in a pickling

solution in a wood, stone or lead-lined tank.

The solution is made with five gallons of commercial sulphuric acid in

150 gallons of water. To get the quickest and best results from this

method, the solution should be kept as near the boiling point as possible

by having a coil of extra heavy lead pipe running inside the tank and

carrying live steam. A very few minutes in this bath will remove the scale

and the parts should then be washed in running water. After this washing

they should be dipped into a bath of 50 pounds of unslaked lime in 150

gallons of water to neutralize any trace of acid.

Cast iron cannot be commercially welded, as it is high in carbon and

silicon, and passes suddenly from a crystalline to a fluid state when

brought to the welding temperature. With steel or wrought iron the

temperature must be kept below the melting point to avoid injury to the

metal. The metal must be heated quickly and pressed together with

sufficient force to push all burnt metal out of the joint.

High carbon steel can be welded, but must be annealed after welding to

overcome the strains set up by the heat being applied at one place. Good

results are hard to obtain when the carbon runs as high as 75 points, and

steel of this class can only be handled by an experienced operator. If the

steel is below 25 points in carbon content, good welds will always be the

result. To weld high carbon to low carbon steel, the stock should be

clamped in the dies with the low carbon stock sticking considerably further

out from the die than the high carbon stock. Nickel steel welds readily,

the nickel increasing the strength of the weld.

Iron and copper may be welded together by reducing the size of the copper

end where it comes in contact with the iron. When welding copper and brass

the pressure must be less than when welding iron. The metal is allowed to

actually fuse or melt at the juncture and the pressure must be sufficient

to force the burned metal out. The current is cut off the instant the metal

ends begin to soften, this being done by means of an automatic switch which

opens when the softening of the metal allows the ends to come together. The

pressure is applied to the weld by having the sliding jaw moved by a weight

on the end of an arm.

Copper and brass require a larger volume of current at a lower voltage than

for steel and iron. The die faces are set apart three times the diameter of

the stock for brass and four times the diameter for copper.

Light gauges of sheet steel can be welded to heavy gauges or to solid bars

of steel by "spot" welding, which will be described later. Galvanized iron

can be welded, but the zinc coating will be burned off. Sheet steel can be

welded to cast iron, but will pull apart, tearing out particles of the

iron.

Sheet copper and sheet brass may be welded, although this work requires

more experience than with iron and steel. Some grades of sheet aluminum can

be spot-welded if the slight roughness left on the surface under the die

is not objectionable.

Butt Welding.—This is the process which joins the ends of two

pieces of metal as described in the foregoing part of this chapter. The

ends are in plain sight of the operator at all times and it can easily be

seen when the metal reaches the welding heat and begins to soften (Figure

46). It is at this point that the pressure must be applied with the lever
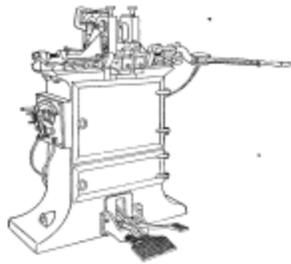
and the ends forced together in the weld.

Image Figure 46.—Butt Welder

The parts are placed in the clamping jaws (Figure 47) with 1/8 to ½ inch

of metal extending beyond the jaw. The ends of the metal touch each other

and the current is turned on by means of a switch. To raise the ends to the

proper heat requires from 3 seconds for ¼-inch rods to 35 seconds for a

1-1/2-inch bar.

This method is applicable to metals having practically the same area of

metal to be brought into contact on each end. When such parts are forced

together a slight projection will be left in the form of a fin or an

enlarged portion called an upset. The degree of heat required for any work

is found by moving the handle of the regulator one way or the other while

testing several parts. When this setting is right the work can continue as
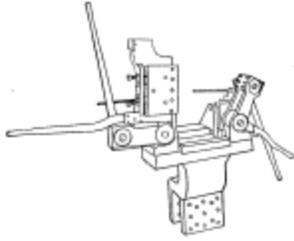
long as the same sizes are being handled.

Image Figure 47.—Clamping Dies of a Butt Welder

Copper, brass, tool steel and all other metals that are harmed by high

temperatures must be heated quickly and pressed together with sufficient

force to force all burned metal from the weld.

In case it is desired to make a weld in the form of a capital letter T, it

is necessary to heat the part corresponding to the top bar of the T to a

bright red, then bring the lower bar to the pre-heated one and again turn

on the current, when a weld can be quickly made.

Spot Welding.—This is a method of joining metal sheets together at

any desired point by a welded spot about the size of a rivet. It is done on

a spot welder by fusing the metal at the point desired and at the same

instant applying sufficient pressure to force the particles of molten metal

together. The dies are usually placed one above the other so that the work

may rest on the lower one while the upper one is brought down on top of the

upper sheet to be welded.

One of the dies is usually pointed slightly, the opposing one being left

flat. The pointed die leaves a slight indentation on one side of the metal,

while the other side is left smooth. The dies may be reversed so that the

outside surface of any work may be left smooth. The current is allowed to

flow through the dies by a switch which is closed after pressure is applied

to the work.

There is a limit to the thickness of sheet metal that can be welded by this

process because of the fact that the copper rods can only carry a certain

quantity of current without becoming unduly heated themselves. Another

reason is that it is difficult to make heavy sections of metal touch at the

welding point without excessive pressure.

Lap welding is the process used when two pieces of metal are caused

to overlap and when brought to a welding heat are forced together by

passing through rollers, or under a press, thus leaving the welded joint

practically the same thickness as the balance of the work.

Where it is desirable to make a continuous seam, a special machine is

required, or an attachment for one of the other types. In this form of work

the stock must be thoroughly cleaned and is then passed between copper

rollers which act in the same capacity as the copper dies.

Other Applications.—Hardening and tempering can be done by clamping

the work in the welding dies and setting the control and time to bring the

metal to the proper color, when it is cooled in the usual manner.

Brazing is done by clamping the work in the jaws and heating until the

flux, then the spelter has melted and run into the joint. Riveting and

heading of rivets can be done by bringing the dies down on opposite ends of

the rivet after it has been inserted in the hole, the dies being shaped to

form the heads properly.

Hardened steel may be softened and annealed so that it can be machined by

connecting the dies of the welder to each side of the point to be softened.

The current is then applied until the work has reached a point at which it

will soften when cooled.

Troubles and Remedies.—The following methods have been furnished by

the Toledo Electric Welder Company and are recommended for this class of

work whenever necessary.

To locate grounds in the primary or high voltage side of the circuit,

connect incandescent lamps in series by means of a long piece of lamp cord,

as shown, in Figure 43a. For 110 volts use one lamp, for 220 volts use two

lamps and for 440 volts use four lamps. Attach one end of the lamp cord to

one side of the switch, and close the switch. Take the other end of the

cord in the hand and press it against some part of the welder frame where

the metal is clean and bright. Paint, grease and dirt act as insulators and

prevent electrical contact. If the lamp lights, the circuit is in

electrical contact with the frame; in other words, grounded. If the lamps

do not light, connect the wire to a terminal block, die or slide. If the

lamps then light, the circuit, coils or leads are in electrical contact

with the large coil in the transformer or its connections.

If, however, the lamps do not light in either case, the lamp cord should be

disconnected from the switch and connected to the other side, and the

operations of connecting to welder frame, dies, terminal blocks, etc., as

explained above, should be repeated. If the lamps light at any of these

connections, a "ground" is indicated. "Grounds" can usually be found by

carefully tracing the primary circuit until a place is found where the

insulation is defective. Reinsulate and make the above tests again to make

sure everything is clear. If the ground can not be located by observation,

the various parts of the primary circuit should be disconnected, and the

transformer, switch, regulator, etc., tested separately.

To locate a ground in the regulator or other

part, disconnect the lines

running to the welder from the switch. The test lamps used in the previous

tests are connected, one end of lamp cord to the switch, the other end to a

binding post of the regulator. Connect the other side of the switch to some

part of the regulator housing. (This must be a clean connection to a bolt

head or the paint should be scraped off.) Close the switch. If the lamps

light, the regulator winding or some part of the switch is "grounded" to

the iron base or core of the regulator. If the lamps do not light, this

part of the apparatus is clear.

This test can be easily applied to any part of the welder outfit by

connecting to the current carrying part of the apparatus, and to the iron

base or frame that should not carry current. If the lamps light, it

indicates that the insulation is broken down or is defective.

An A.C. voltmeter can, of course, be substituted for the lamps, or a D.C.

voltmeter with D.C. current can be used in making the tests.

A short circuit in the primary is caused by the insulation of the coils

becoming defective and allowing the bare copper wires to touch each other.

This may result in a "burn out" of one or more of the transformer coils, if

the trouble is in the transformer, or in the continued blowing of fuses in

the line. Feel of each coil separately. If a short circuit exists in a coil

it will heat excessively. Examine all the wires; the insulation may have

worn through and two of them may cross, or be in contact with the frame or

other part of the welder. A short circuit in the regulator winding is

indicated by failure of the apparatus to regulate properly, and sometimes,

though not always, by the heating of the regulator coils.

The remedy for a short circuit is to reinsulate the defective parts. It is

a good plan to prevent trouble by examining the wiring occasionally and see

that the insulation is perfect.

To Locate Grounds and Short Circuits in the Secondary, or Low Voltage

Side.—Trouble of this kind is indicated by the machine acting sluggish

or, perhaps, refusing to operate. To make a test, it will be necessary to

first ascertain the exciting current of your particular transformer. This

is the current the transformer draws on "open circuit," or when supplied

with current from the line with no stock in the welder dies. The following

table will give this information close enough for all practical purposes:

K.W. Rating	---------------- Amperes at ----------------			
	110 Volts	220 Volts	440 Volts	550 Volts
3	1.5	.75	.38	.3
5	2.5	1.25	.63	.5
8	3.6	1.8	.9	.72
10	4.25	2.13	1.07	.85
15	6.	3.	1.5	1.2
20	7.	3.5	1.75	1.4
30	9.	4.5	2.25	1.8
35	9.6	4.8	2.4	1.92
50	10.	5.	2.5	2

Remove the fuses from the wall switch and substitute fuses just large

enough to carry the "exciting" current. If no suitable fuses are at hand,

fine strands of copper from an ordinary lamp cord may be used. These

strands are usually No. 30 gauge wire and will fuse at about 10 amperes.

One or more strands should be used, depending on the amount of exciting

current, and are connected across the fuse clips in place of fuse wire.

Place a piece of wood or fiber between the welding dies in the welder as

though you were going to weld them. See that the regulator is on the

highest point and close the welder switch. If the secondary circuit is

badly grounded, current will flow through the ground, and the small fuses

or small strands of wire will burn out. This is an indication that both

sides of the secondary circuit are grounded or that a short circuit exists

in a primary coil. In either case the welder should not be operated until

the trouble is found and removed. If, however, the small fuses do not

"blow," remove same and replace the large fuses, then disconnect wires

running from the wall switch to the welder and substitute two pieces of

No. 8 or No. 6 insulated copper wire, after scraping off the insulation for

an inch or two at each end. Connect one wire from the switch to the frame

of welder; this will leave one loose end. Hold this a foot or so away from

the place where the insulation is cut off; then turn on the current and

strike the free end of this wire lightly against one of the copper dies,

drawing it away quickly. If no sparking is produced, the secondary circuit

is free from ground, and you will then look for a broken connection in the

circuit. Some caution must be used in making the above test, as in case one

terminal is heavily grounded the testing wire may be fused if allowed to

stay in contact with the die.

The Remedy.—Clean the slides, dies and terminal blocks thoroughly

and dry out the fiber insulation if it is damp. See that no scale or metal

has worked under the sliding parts, and that the secondary leads do not

touch the frame. If the ground is very heavy it may be necessary to remove

the slides in order to facilitate the examination

and removal of the

ground. Insulation, where torn or worn through, must be carefully replaced

or taped. If the transformer coils are grounded to the iron core of the

transformer or to the secondary, it may be necessary to remove the coils

and reinsulate them at the points of contact. A short circuited coil will

heat excessively and eventually burn out. This may mean a new coil if you

are unable to repair the old one. In all cases the transformer windings

should be protected from mechanical injury or dampness. Unless excessively

overloaded, transformers will last for years without giving a moment's

trouble, if they are not exposed to moisture or are not injured

mechanically.

The most common trouble arises from poor electrical contacts, and they are

the cause of endless trouble and annoyance. See that all connections are

clean and bright. Take out the dies every day or two and see that there is

no scale, grease or dirt between them and the holders. Clean them

thoroughly before replacing. Tighten the bolts running from the transformer

leads to the work jaws.

ELECTRIC ARC WELDING

This method bears no relation to the one just considered, except that the

source of heat is the same in both cases. Arc welding makes use of the

flame produced by the voltaic arc in practically the same way that

oxy-acetylene welding uses the flame from the gases.

If the ends of two pieces of carbon through which a current of electricity

is flowing while they are in contact are separated from each other quite

slowly, a brilliant arc of flame is formed between them which consists

mainly of carbon vapor. The carbons are consumed by combination with the

oxygen in the air and through being turned to a gas under the intense heat.

The most intense action takes place at the center of the carbon which

carries the positive current and this is the point of greatest heat. The

temperature at this point in the arc is greater than can be produced by any

other means under human control.

An arc may be formed between pieces of metal, called electrodes, in the

same way as between carbon. The metallic arc is called a flaming arc and as

the metal of the electrode burns with the heat, it gives the flame a color

characteristic of the material being used. The metallic arc may be drawn

out to a much greater length than one formed between carbon electrodes.

Arc Welding is carried out by drawing a piece of carbon which is of

negative polarity away from the pieces of metal to be welded while the

metal is made positive in polarity. The negative wire is fastened to the

carbon electrode and the work is laid on a table made of cast or wrought

iron to which the positive wire is made fast. The direction of the flame is

then from the metal being welded to the carbon and the work is thus

prevented from being saturated with carbon, which would prove very

detrimental to its strength. A secondary advantage is found in the fact

that the greatest heat is at the metal being welded because of its being

the positive electrode.

The carbon electrode is usually made from one quarter to one and a half

inches in diameter and from six to twelve inches in length. The length of

the arc may be anywhere from one inch to four inches, depending on the size

of the work being handled.

While the parts are carefully insulated to avoid danger of shock, it is

necessary for the operator to wear rubber gloves as a further protection,

and to wear some form of hood over the head to shield him against the

extreme heat liberated. This hood may be made from metal, although some

material that does not conduct electricity is to be preferred. The work is

watched through pieces of glass formed with one sheet, which is either blue

or green, placed over another which is red. Screens of glass are sometimes

used without the head protector. Some protection for the eyes is absolutely

necessary because of the intense white light.

It is seldom necessary to preheat the work as with the gas processes,

because the heat is localized at the point of welding and the action is so

rapid that the expansion is not so great. The necessity of preheating,

however, depends entirely on the material, form and size of the work being

handled. The same advice applies to arc welding as to the gas flame method

but in a lesser degree. Filling rods are used in the same way as with any

other flame process.

It is the purpose of this explanation to state the fundamental principles

of the application of the electric arc to welding metals, and by applying

the principles the following questions will be answered:

What metals can be welded by the electric arc?

What difficulties are to be encountered in applying the electric arc to

welding?

What is the strength of the weld in comparison with the original piece?

What is the function of the arc welding machine itself?

What is the comparative application of the electric arc and the

oxy-acetylene method and others of a similar

nature?

The answers to these questions will make it possible to understand the

application of this process to any work. In a great many places the use of

the arc is cutting the cost of welding to a very small fraction of what it

would be by any other method, so that the importance of this method may be

well understood.

Any two metals which are brought to the melting temperature and applied to

each other will adhere so that they are no more apt to break at the weld

than at any other point outside of the weld. It is the property of all

metals to stick together under these conditions. The electric arc is used

in this connection merely as a heating agent. This is its only function in

the process.

It has advantages in its ease of application and the cheapness with which

heat can be liberated at any given point by its use. There is nothing in

connection with arc welding that the above principles will not answer; that

is, that metals at the melting point will weld and that the electric arc

will furnish the heat to bring them to this point. As to the first

question, what metals can be welded, all metals can be welded.

The difficulties which are encountered are as follows:

In the case of brass or zinc, the metals will be covered with a coat of

zinc oxide before they reach a welding heat. This zinc oxide makes it

impossible for two clean surfaces to come together and some method has to

be used for eliminating this possibility and allowing the two surfaces to

join without the possibility of the oxide intervening. The same is true of

aluminum, in which the oxide, alumina, will be formed, and with several

other alloys comprising elements of different melting points.

In order to eliminate these oxides, it is necessary in practical work, to

puddle the weld; this is, to have a sufficient quantity of molten metal at

the weld so that the oxide is floated away. When this is done, the two

surfaces which are to be joined are covered with a coat of melted metal on

which floats the oxide and other impurities. The two pieces are thus

allowed to join while their surfaces are protected. This precaution is not

necessary in working with steel except in extreme cases.

Another difficulty which is met with in the welding of a great many metals

is their expansion under heat, which results in so great a contraction when

the weld cools that the metal is left with a considerable strain on it. In

extreme cases this will result in cracking at the weld or near it. To

eliminate this danger it is necessary to apply heat either all over the

piece to be welded or at certain points. In the case of cast iron and

sometimes with copper it is necessary to anneal after welding, since

otherwise the welded pieces will be very brittle on account of the

chilling. This is also true of malleable iron.

Very thin metals which are welded together and are not backed up by

something to carry away the excess heat, are very apt to burn through,

leaving a hole where the weld should be. This difficulty can be eliminated

by backing up the weld with a metal face or by decreasing the intensity of

the arc so that this melting through will not occur. However, the practical

limit for arc welding without backing up the work with a metal face or

decreasing the intensity of the arc is approximately 22 gauge, although

thinner metal can be welded by a very skillful

and careful operator.

One difficulty with arc welding is the lack of skillful operators. This

method is often looked upon as being something out of the ordinary and

governed by laws entirely different from other welding. As a matter of

fact, it does not take as much skill to make a good arc weld as it does to

make a good weld in a forge fire as the blacksmith does it. There are few

jobs which cannot be handled successfully by an operator of average

intelligence with one week's instructions, although his work will become

better and better in quality as he continues to use the arc.

Now comes the question of the strength of the weld after it has been made.

This strength is equally as great as that of the metal that is used to make

the weld. It should be remembered, however, that the metal which goes into

the weld is put in there as a casting and has not been rolled. This would

make the strength of the weld as great as the same metal that is used for

filling if in the cast form.

Two pieces of steel could be welded together having a tensile strength at

the weld of 50,000 pounds. Higher strengths than this can be obtained by

the use of special alloys for the filling material or by rolling. Welds

with a tensile strength as great as mentioned will give a result which is

perfectly satisfactory in almost all cases.

There are a great many jobs where it is possible to fill up the weld, that

is, make the section at the point of the weld a little larger than the

section through the rest of the piece. By doing this, the disadvantages

of the weld being in the form of a casting in comparison with the rest of

the piece being in the form of rolled steel can be overcome, and make the

weld itself even stronger than the original piece.

The next question is the adaptability of the electric arc in comparison

with forge fire, oxy-acetylene or other method. The answer is somewhat

difficult if made general. There are no doubt some cases where the use of a

drop hammer and forge fire or the use of the oxy-acetylene torch will make,

all things being considered, a better job than the use of the electric arc,

although a case where this is absolutely proved is rare.

The electric arc will melt metal in a weld for less than the same metal can

be melted by the use of the oxy-acetylene torch, and, on account of the

fact that the heat can be applied exactly where it is required and in the

amount required, the arc can in almost all cases supply welding heat for

less cost than a forge fire or heating furnace.

The one great advantage of the oxy-acetylene method in comparison with

other methods of welding is the fact that in some cases of very thin sheet,

the weld can be made somewhat sooner than is possible otherwise. With metal

of 18 gauge or thicker, this advantage is eliminated. In cutting steel, the

oxy-acetylene torch is superior to almost any other possible method.

Arc Welding Machines.—A consideration of the function and purpose

of the various types of arc welding machines shows that the only reason for

the use of any machine is either for conversion of the current from

alternating to direct, or, if the current is already direct, then the

saving in the application of this current in the arc.

It is practically out of the question to apply an alternating current arc

to welding for the reason that in any arc practically all the heat is

liberated at the positive electrode, which means

that, in alternating

current, half the heat is liberated at each electrode as the current

changes its direction of flow or alternates. Another disadvantage of the

alternating arc is that it is difficult of control and application.

In all arc welding by the use of the carbon arc, the positive electrode is

made the piece to be welded, while in welding with metallic electrodes this

may be either the piece to be welded of the rod that is used as a filler.

The voltage across the arc is a variable quantity, depending on the length

of the flame, its temperature and the gases liberated in the arc. With a

carbon electrode the voltage will vary from zero to forty-five volts. With

the metallic electrode the voltage will vary from zero to thirty volts. It

is, therefore, necessary for the welding machine to be able to furnish to

the arc the requisite amount of current, this amount being varied, and

furnish it at all times at the voltage required.

The simplest welding apparatus is a resistance in series with the arc. This

is entirely satisfactory in every way except in cost of current. By the use

of resistance in series with the arc and using 220 volts as the supply,

from eighty to ninety per cent of the current is lost in heat at the

resistance. Another disadvantage is the fact that most materials change

their resistance as their temperature changes, thus making the amount of

current for the arc a variable quantity, depending on the temperature of

the resistance.

There have been various methods originated for saving the power mentioned

and a good many machines have been put on the market for this purpose. All

of them save some power over what a plain resistance would use. Practically

all arc welding machines at the present time are motor generator sets, the

motor of which is arranged for the supply voltage and current, this motor

being direct connected to a compound wound generator delivering

approximately seventy-five volts direct current. Then by the use of a

resistance, this seventy-five volt supply is applied to the arc. Since the

voltage across the arc will vary from zero to fifty volts, this machine

will save from zero up to seventy per cent of the power that the machine

delivers. The rest of the power, of course, has to be dissipated in the

resistance used in series with the arc.

A motor generator set which can be purchased from any electrical company,

with a long piece of fence wire wound around a piece of asbestos, gives

results equally as good and at a very small part of the first cost.

It is possible to construct a machine which will eliminate all losses in

the resistance; in other words, eliminate all resistance in series with the

arc. A machine of this kind will save its cost within a very short time,

providing the welder is used to any extent.

Putting it in figures, the results are as follows for average conditions.

Current at 2c per kilowatt hour, metallic electrode arc of 150 amperes,

carbon arc 500 amperes; voltage across the metallic electrode arc 20,

voltage across the carbon arc 35. Supply current 220 volts, direct. In the

case of the metallic electrode, if resistance is used, the cost of running

this arc is sixty-six cents per hour. With the carbon electrode, $2.20 per

hour. If a motor generator set with a seventy volt constant potential

machine is used for a welder, the cost will be as follows:

Metallic electrode 25.2c. Carbon electrode 84c per hour. With a machine

which will deliver the required voltage at the arc and eliminate all the

resistance in series with the arc, the cost will be as follows: Metallic

electrode 7.2c per hour; carbon electrode 42c per hour. This is with the

understanding that the arc is held constant and continuously at its full

value. This, however, is practically impossible and the actual load factor

is approximately fifty per cent, which would mean that operating a welder

as it is usually operated, this result will be reduced to one-half of that

stated in all cases.

CHAPTER VII

HAND FORGING AND WELDING

Smithing, or blacksmithing, is the process of working heated iron, steel or

other metals by forging, bending or welding them.

The Forge.—The metal is heated in a forge consisting of a shallow

pan for holding the fire, in the center of which is an opening from below

through which air is forced to make a hot fire.
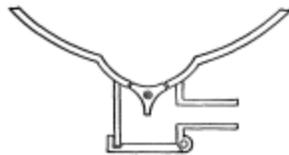
Image Figure 48.—Tuyere Construction on a Forge

Air is forced through this hole, called a "tuyere" (Figure 48) by means of

a hand bellows, a rotary fan operated with crank or lever, or with a fan

driven from an electric motor. The harder the air is driven into the fire

above the tuyere the more oxygen is furnished and the hotter the fire

becomes.

Directly below the tuyere is an opening through which the ashes that drop

from the fire may be cleaned out.

The Fire.—The fire is made by placing a small piece of waste soaked

in oil, kerosene or gasoline, over the tuyere, lighting the waste, then

starting the fan or blower slowly. Gradually cover the waste, while it is

burning brightly, with a layer of soft coal. The coal will catch fire and

burn after the waste has been consumed. A piece of waste half the size of a

person's hand is ample for this purpose.

The fuel should be "smithing coal." A lump of smithing coal breaks easily,

shows clean and even on all sides and should not break into layers. The

coal is broken into fine pieces and wet before being used on the fire.

The fire should be kept deep enough so that there is always three or four

inches of fire below the piece of metal to be heated and there should be

enough fire above the work so that no part of the metal being heated comes

in contact with the air. The fire should be kept as small as possible while

following these rules as to depth.

To make the fire larger, loosen the coal around the edges. To make the fire

smaller, pack wet coal around the edges in a compact mass and loosen the

fire in the center. Add fresh coal only around the edges of the fire. It

will turn to coke and can then be raked onto the fire. Blow only enough air

into the fire to keep it burning brightly, not so much that the fire is

blown up through the top of the coal pack. To prevent the fire from going

out between jobs, stick a piece of soft wood into it and cover with fresh

wet coal.

Tools.—The hammer is a ball pene, or blacksmith's hammer,

weighing about a pound and a half.

The sledge is a heavy hammer, weighing from 5 to 20 pounds and

having a handle 30 to 36 inches long.

The anvil is a heavy piece of wrought iron (Figure 49), faced with

steel and having four legs. It has a pointed horn on one end, an

overhanging tail on the other end and a flat top. In the tail there is a

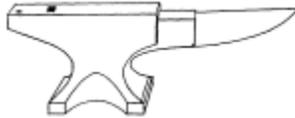square hole called the "hardie" hole and a round one called the "spud"

hole.

Image Figure 49.—Anvil, Showing Horn, Tail, Hardie Hole and Spud

Hole

Tongs, with handles about one foot long and jaws suitable for

holding the work, are used. To secure a firm grip on the work, the jaws may

be heated red hot and hammered into shape over the piece to be held, thus

giving a properly formed jaw. Jaws should touch the work along their entire

length.

The set hammer is a hammer, one end of whose head is square and

flat, and from this face the head tapers evenly to the other face. The

large face is about 1-1/4 inches square.

The flatter is a hammer having one face of its head flat and about

2-1/2 inches square.

Swages are hammers having specially formed faces for finishing

rounds, squares, hexagons, ovals, tapers, etc.

Fullers are hammers having a rounded face, long in one direction.

They are used for spreading metal in one direction only.

The hardy is a form of chisel with a short, square shank which may

be set into the hardie hole for cutting off hot bars.

Operations.—Blacksmithing consists of bending, drawing or upsetting

with the various hammers, or in punching holes.

Bending is done over the square corners of the anvil if square cornered

bends are desired, or over the horn of the anvil if rounding bends, eyes,

hooks, etc., are wanted.

To bend a ring or eye in the end of a bar, first figure the length of stock

needed by multiplying the diameter of the hole by 31/7, then heat the piece

to a good full red at a point this distance back from the end. Next bend

the iron over at a 90 degree angle (square) at this point. Next, heat the

iron from the bend just made clear to the point and make the eye by laying

the part that was bent square over the horn of the anvil and bending the

extreme tip into part of a circle. Keep pushing the piece farther and

farther over the horn of the anvil, bending it as you go. Do not hammer

directly over the horn of the anvil, but on the side where you are doing

the bending.

To make the outside of a bend square, sharp and full, rather than slightly

rounding, the bent piece must be laid edgewise on the face of the anvil.

That is, after making the bend over the corner of the anvil, lay the piece

on top of the anvil so that its edge and not the flat side rests on the

anvil top. With the work in this position, strike directly against the

corner with the hammer so that the blows come in line, first with one leg

of the work, then the other, and always directly on the corner of the

piece. This operation cannot be performed by laying the work so that one

leg hangs over the anvil's corner.

To make a shoulder on a rod or bar, heat the work and lay flat across the

top of the anvil with the point at which the shoulder is desired at the

edge of the anvil. Then place the set hammer on

top of the piece, with the

outside edge of the set hammer directly over the edge of the anvil. While

hammering in this position keep the work turning continually.

To draw stock means to make it longer and thinner by hammering. A piece to

be drawn out is usually laid across the horn of the anvil while being

struck with the hammer. The metal is then spread in only one direction in

place of being spread in every direction, as it would be if laid on the

anvil face. To draw the work, heat it to as high a temperature as it will

stand without throwing sparks and burning. The fuller may be used for

drawing metal in place of laying the work over the horn of the anvil.

When drawing round stock, it should be first drawn out square, and when

almost down to size it may be rounded. When pointing stock, the same rule

of first drawing out square applies.

Upsetting means to make a piece shorter in length and greater in thickness

or width, or both shorter and thicker. To upset short pieces, heat to a

bright red at the place to be upset, then stand on end on the anvil face

and hammer directly down on top until of the right form. Longer pieces may

be swung against the anvil or placed upright on a heavy piece of metal

lying on the floor or that is sunk into the floor. While standing on this

heavy piece the metal may be upset by striking down on the end with a heavy

hammer or the sledge. If a bend appears while upsetting, it should be

straightened by hammering back into shape on the anvil face.

Light blows affect the metal for only a short distance from the point of

striking, but heavy blows tend to swell the metal more equally through its

entire length. In driving rivets that should fill the holes, heavy blows

should be struck, but to shape the end of a rivet or to make a head on a

rod, light blows should be used.

The part of the piece that is heated most will upset the most.

To punch a hole through metal, use a tool steel punch with its end slightly

tapering to a size a little smaller than the hole to be punched. The end of

the punch must be square across and never pointed or rounded.

First drive the punch part way through from one side and then turn the work

over. When you turn it over, notice where the bulge appears and in that way

locate the hole and drive the punch through from the second side. This

makes a cleaner and more even hole than to drive completely through from

one side. When the punch is driven in from the second side, the place to be

punched through should be laid over the spud hole in the tail of the anvil

and the piece driven out of the work.

Work when hot is larger than it will be after cooling. This must be

remembered when fitting parts or trouble will result. A two-foot bar of

steel will be ¼ inch longer when red hot than when cold.

The temperatures of iron correspond to the following colors:

Dullest red seen in the dark... 878°

Dullest red seen in daylight... 887°

Dull red...................... 1100°

Full red...................... 1370°

Light red..................... 1550°

Orange........................ 1650°

Light orange.................. 1725°

Yellow........................ 1825°

Light yellow.................. 1950°

Bending Pipes and Tubes.—It is difficult to make bends or curves in

pipes and tubing without leaving a noticeable bulge at some point of the

work. Seamless steel tubing may be handled

without very great danger of

this trouble if care is used, but iron pipe, having a seam running

lengthwise, must be given special attention to avoid opening the seam.

Bends may be made without kinking if the tube or pipe is brought to a full

red heat all the way around its circumference and at the place where the

bend is desired. Hold the cool portion solidly in a vise and, by taking

hold of the free end, bend very slowly and with a steady pull. The pipe

must be kept at full red heat with the flames from one or more torches and

must not be hammered to produce the bend. If a sufficient purchase cannot

be secured on the free end by the hand, insert a piece of rod or a smaller

pipe into the opening.

While making the bend, should small bulges appear, they may be hammered

back into shape before proceeding with the work.

Tubing or pipes may be bent while being held between two flat metal

surfaces while at a bright red heat. The metal plates at each side of the

work prevent bulging.

Another method by which tubing may be bent consists of filling completely

with tightly packed sand and fitting a solid cap or plug at each end.

Thin brass tubing may be filled with melted resin and may be bent after the

resin cools. To remove the resin it is necessary to heat the tube, allowing

it to run out.

Large jobs of bending should be handled in special pipe bending machines in

which the work is forced through formed rolls which prevent its bulging.

WELDING

Welding with the heat of a blacksmith forge fire, or a coal or illuminating

gas fire, can only be performed with iron and steel because of the low heat

which is not localized as with the oxy-acetylene and electric processes.

Iron to be welded in this manner is heated until it reaches the temperature

indicated by an orange color, not white, as is often stated, this orange

color being slightly above 3600 degrees Fahrenheit. Steel is usually welded

at a bright red heat because of the danger of oxidizing or burning the

metal if the temperature is carried above this point.

The Fire.—If made in a forge, the fire should be built from good

smithing coal or, better still, from coke. Gas fires are, of course,

produced by suitable burners and require no special preparation except

adjustment of the heat to the proper degree for the size and thickness of

the metal being welded so that it will not be burned.

A coal fire used for ordinary forging operations should not be used for

welding because of the impurities it contains. A fresh fire should be built

with a rather deep bed of coal, four to eight inches being about right for

work ordinarily met with. The fire should be kept burning until the coal

around the edges has been thoroughly coked and a sufficient quantity of

fuel should be on and around the fire so that no fresh coal will have to

be added while working.

After the coking process has progressed sufficiently, the edges should be

packed down and the fire made as small as possible while still surrounding

the ends to be joined. The fire should not be altered by poking it while

the metal is being heated. The best form of fire to use is one having

rather high banks of coked coal on each side of the mass, leaving an

opening or channel from end to end. This will allow the added fuel to be

brought down on top of the fire with a small

amount of disturbance.

Preparing to Weld.—If the operator is not familiar with the metal

to be handled, it is best to secure a test piece if at all possible and try

heating it and joining the ends. Various grades of iron and steel call for

different methods of handling and for different degrees of heat, the proper

method and temperature being determined best by actual test under the

hammer.

The form of the pieces also has a great deal to do with their handling,

especially in the case of a more or less inexperienced workman. If the

pieces are at all irregular in shape, the motions should be gone through

with before the metal is heated and the best positions on the anvil as well

as in the fire determined with regard to the convenience of the workman and

speed of handling the work after being brought to a welding temperature.

Unnatural positions at the anvil should be avoided as good work is most

difficult of performance under these conditions.

Scarfing.—While there are many forms of welds, depending on the

relative shape of the pieces to be joined, the portions that are to meet

and form one piece are always shaped in the same general way, this shape

being called a "scarf." The end of a piece of work, when scarfed, is

tapered off on one side so that the extremity comes to a rather sharp edge.

The other side of the piece is left flat and a continuation in the same

straight plane with its side of the whole piece of work. The end is then in

the form of a bevel or mitre joint (Figure 50).

Image Figure 50.—Scarfing Ends of Work Ready for Welding

Scarfing may be produced in any one of several

ways. The usual method is to

bring the ends to a forging heat, at which time they are upset to give a

larger body of metal at the ends to be joined. This body of metal is then

hammered down to the taper on one side, the length of the tapered portion

being about one and a half times the thickness of the whole piece being

handled. Each piece should be given this shape before proceeding farther.

The scarf may be produced by filing, sawing or chiseling the ends, although

this is not good practice because it is then impossible to give the desired

upset and additional metal for the weld. This added thickness is called for

by the fact that the metal burns away to a certain extent or turns to

scale, which is removed before welding.

When the two ends have been given this shape they should not fit as closely

together as might be expected, but should touch only at the center of the

area to be joined (Figure 51). That is to say, the surface of the beveled

portion should bulge in the middle or should be convex in shape so that the

edges are separated by a little distance when the pieces are laid together

with the bevels toward each other. This is done so that the scale which is

formed on the metal by the heat of the fire can have a chance to escape

from the interior of the weld as the two parts are forced together.

Image Figure 51.—Proper Shape of Scarfed Ends

If the scarf were to be formed with one or more of the edges touching each

other at the same time or before the centers did so, the scale would be

imprisoned within the body of the weld and would cause the finished work to

be weak, while possibly giving a satisfactory appearance from the outside.

Fluxes.—In order to assist in removing the scale and other

impurities and to make the welding surfaces as clean as possible while

being joined, various fluxing materials are used as in other methods of

welding.

For welding iron, a flux of white sand is usually used, this material being

placed on the metal after it has been brought to a red heat in the fire.

Steel is welded with dry borax powder, this flux being applied at the same

time as the iron flux just mentioned. Borax may also be used for iron

welding and a mixture of borax with steel borings may also be used for

either class of work. Mixtures of sal ammoniac with borax have been

successfully used, the proportions being about four parts of borax to one

of sal ammoniac. Various prepared fluxing powders are on the market for

this work, practically all of them producing satisfactory results.

After the metal has been in the fire long enough to reach a red heat, it is

removed temporarily and, if small enough in size, the ends are dipped into

a box of flux. If the pieces are large, they may simply be pulled to the

edge of the fire and the flux then sprinkled on the portions to be joined.

A greater quantity of flux is required in forge welding than in electric or

oxy-acetylene processes because of the losses in the fire. After the powder

has been applied to the surfaces, the work is returned to the fire and

heated to the welding temperature.

Heating the Work.—After being scarfed, the two pieces to be welded

are placed in the fire and brought to the correct temperature. This

temperature can only be recognized by experiment and experience. The metal

must be just below that point at which small sparks begin to be thrown out

of the fire and naturally this is a hard point to distinguish. At the

welding heat the metal is almost ready to flow and is about the consistency

of putty. Against the background of the fire and coal the color appears to

be a cream or very light yellow and the work feels soft as it is handled.

It is absolutely necessary that both parts be heated uniformly and so that

they reach the welding temperature at the same time. For this reason they

should be as close together in the fire as possible and side by side. When

removed to be hammered together, time is saved if they are picked up in

such a way that when laid together naturally the beveled surfaces come

together. This makes it necessary that the workman remember whether the

scarfed side is up or down, and to assist in this it is a good thing to

mark the scarfed side with chalk or in some other noticeable manner, so

that no mistake will be made in the hurry of placing the work on the anvil.

The common practice in heating allows the temperature to rise until the

small white sparks are seen to come from the fire. Any heating above this

point will surely result in burning that will ruin the iron or steel being

handled. The best welding heat can be discerned by the appearance of the

metal and its color after experience has been gained with this particular

material. Test welds can be made and then broken, if possible, so that the

strength gained through different degrees of heat can be known before

attempting more important work.

Welding.—When the work has reached the welding temperature after

having been replaced in the fire with the flux applied, the two parts are

quickly tapped to remove the loose scale from their surfaces. They are then

immediately laid across the top of the anvil,

being placed in a diagonal

position if both pieces are straight. The lower piece is rested on the

anvil first with the scarf turned up and ready to receive the top piece in

the position desired. The second piece must be laid in exactly the position

it is to finally occupy because the two parts will stick together as soon

as they touch and they cannot well be moved after having once been allowed

to come in contact with each other. This part of the work must be done

without any unnecessary loss of time because the comparatively low heat at

which the parts weld allows them to cool below the working temperature in

a few seconds.

The greatest difficulty will be experienced in withdrawing the metal from

the fire before it becomes burned and in getting it joined before it cools

below this critical point. The beveled edges of the scarf are, of course,

the first parts to cool and the weld must be made before they reach a point

at which they will not join, or else the work will be defective in

appearance and in fact.

If the parts being handled are of such a shape that there is danger of

bending a portion back of the weld, this part may be cooled by quickly

dipping it into water before laying the work on the anvil to be joined.

The workman uses a heavy hand hammer in making the joint, and his helper,

if one is employed, uses a sledge. With the two parts of the work in place

on the anvil, the workman strikes several light blows, the first ones being

at a point directly over the center of the weld, so that the joint will

start from this point and be worked toward the edges. After the pieces have

united the helper strikes alternate blows with his sledge, always striking

in exactly the same place as the last stroke of the workman. The hammer

blows are carried nearer and nearer to the edges of the weld and are made

steadily heavier as the work progresses.

The aim during the first part of the operation should be to make a perfect

joint, with every part of the surfaces united, and too much attention

should not be paid to appearance, at least not enough to take any chance

with the strength of the work.

It will be found, after completion of the weld, that there has been a loss

in length equal to one-half the thickness of the metal being welded. This

loss is occasioned by the burned metal and the scale which has been formed.

Finishing the Weld.—If it is possible to do so, the material should

be hammered into the shape that it should remain with the same heat that

was used for welding. It will usually be found, however, that the metal has

cooled below the point at which it can be worked to advantage. It should

then be replaced in the fire and brought back to a forging heat.

Image Figure 52.—Upsetting and Scarfing the End of a Rod

While shaping the work at this forging heat every part that has been at a

red heat should be hammered with uniformly light and even blows as it

cools. This restores the grain and strength of the iron or steel to a great

extent and makes the unavoidable weakness as small as possible.

Forms of Welds.—The simplest of all welds is that called a "lap

weld." This is made between the ends of two pieces of equal size and

similar form by scarfing them as described and then laying one on top of

the other while they are hammered together.

A butt weld (Figure 52) is made between the ends of two pieces of shaft or

other bar shapes by upsetting the ends so that they have a considerable

flare and shaping the face of the end so that it is slightly higher in the

center than around the edges, this being done to make the centers come

together first. The pieces are heated and pushed into contact, after which

the hammering is done as with any other weld.

Image Figure 53.—Scarfing for a T Weld

A form similar to the butt weld in some ways is used for joining the end of

a bar to a flat surface and is called a jump weld. The bar is shaped in the

same way as for a butt weld. The flat plate may be left as it is, but if

possible a depression should be made at the point where the shaft is to be

placed. With the two parts heated as usual, the bar is dropped into

position and hammered from above. As soon as the center of the weld has

been made perfect, the joint may be finished with a fuller driven all the

way around the edge of the joint.

When it is required to join a bar to another bar or to the edge of any

piece at right angles the work is called a "T" weld from its shape when

complete (Figure 53). The end of the bar is scarfed as described and the

point of the other bar or piece where the weld is to be made is hammered so

that it tapers to a thin edge like one-half of a circular depression. The

pieces are then laid together and hammered as for a lap weld.

The ends of heavy bar shapes are often joined with a "V," or cleft, weld.

One bar end is shaped so that it is tapering on both sides and comes to a

broad edge like the end of a chisel. The other bar is heated to a forging

temperature and then slit open in a lengthwise direction so that the

V-shaped opening which is formed will just receive the pointed edge of the

first piece. With the work at welding heat, the two parts are driven

together by hammering on the rear ends and the hammering then continues as

with a lap weld, except that the work is turned over to complete both sides

of the joint.

Image Figure 54.-Splitting Ends to Be Welded in Thin Work

The forms so far described all require that the pieces be laid together in

the proper position after removal from the fire, and this always causes a

slight loss of time and a consequent lowering of the temperature. With very

light stock, this fall of temperature would be so rapid that the weld would

be unsuccessful, and in this case the "lock" weld is resorted to. The ends

of the two pieces to be joined are split for some distance back, and

one-half of each end is bent up and the other half down (Figure 54). The

two are then pushed together and placed in the fire in this position. When

the welding heat is reached, it is only necessary to take the work out of

the fire and hammer the parts together, inasmuch as they are already in the

correct position.

Other forms of welds in which the parts are too small to retain their heat,

can be made by first riveting them together or cutting them so that they

can be temporarily fastened in any convenient way when first placed in the

fire.

CHAPTER VIII

SOLDERING, BRAZING AND THERMIT WELDING

SOLDERING

Common solder is an alloy of one-half lead with one-half tin, and is called

"half and half." Hard solder is made with two-thirds tin and one-third

lead. These alloys, when heated, are used to join surfaces of the same or

dissimilar metals such as copper, brass, lead, galvanized iron, zinc,

tinned plate, etc. These metals are easily joined, but the action of solder

with iron, steel and aluminum is not so satisfactory and requires greater

care and skill.

The solder is caused to make a perfect union with the surfaces treated with

the help of heat from a soldering iron. The soldering iron is made from a

piece of copper, pointed at one end and with the other end attached to an

iron rod and wooden handle. A flux is used to remove impurities from the

joint and allow the solder to secure a firm union with the metal surface.

The iron, and in many cases the work, is heated with a gasoline blow torch,

a small gas furnace, an electric heater or an acetylene and air torch.

The gasoline torch which is most commonly used should be filled two-thirds

full of gasoline through the hole in the bottom, which is closed by a screw

plug. After working the small hand pump for 10 to 20 strokes, hold the palm

of your hand over the end of the large iron tube on top of the torch and

open the gasoline needle valve about a half turn. Hold the torch so that

the liquid runs down into the cup below the tube and fills it. Shut the

gasoline needle valve, wipe the hands dry, and set fire to the fuel in the

cup. Just as the gasoline fire goes out, open the

gasoline needle valve

about a half turn and hold a lighted match at the end of the iron tube to

ignite the mixture of vaporized gasoline and air. Open or close the needle

valve to secure a flame about 4 inches long.

On top of the iron tube from which the flame issues there is a rest for

supporting the soldering iron with the copper part in the flame. Place the

iron in the flame and allow it to remain until the copper becomes very hot,

not quite red, but almost so.

A new soldering iron or one that has been misused will have to be "tinned"

before using. To do this, take the iron from the fire while very hot and

rub the tip on some flux or dip it into soldering acid. Then rub the tip of

the iron on a stick of solder or rub the solder on the iron. If the solder

melts off the stick without coating the end of the iron, allow a few drops

to fall on a piece of tin plate, then nil the end of the iron on the tin

plate with considerable force. Alternately rub the iron on the solder and

dip into flux until the tip has a coating of bright solder for about half

an inch from the end. If the iron is in very bad shape, it may be necessary

to scrape or file the end before dipping in the flux for the first time.

After the end of the iron is tinned in this way, replace it on the rest of

the torch so that the tinned point is not directly in the flame, turning

the flame down to accomplish this.

Flux.—The commonest flux, which is called "soldering acid," is made

by placing pieces of zinc in muriatic (hydrochloric) acid contained in a

heavy glass or porcelain dish. There will be bubbles and considerable heat

evolved and zinc should be added until this action ceases and the zinc

remains in the liquid, which is now chloride of

zinc.

This soldering acid may be used on any metal to be soldered by applying

with a brush or swab. For electrical work, this acid should be made neutral

by the addition of one part ammonia and one part water to each three parts

of the acid. This neutralized flux will not corrode metal as will the

ordinary acid.

Powdered resin makes a good flux for lead, tin plate, galvanized iron and

aluminum. Tallow, olive oil, beeswax and vaseline are also used for this

purpose. Muriatic acid may be used for zinc or galvanized iron without the

addition of the zinc, as described in making zinc chloride. The addition of

two heaping teaspoonfuls of sal ammoniac to each pint of the chloride of

zinc is sometimes found to improve its action.

Soldering Metal Parts.—All surfaces to be joined should be fitted

to each other as accurately as possible and then thoroughly cleaned with a

file, emery cloth, scratch bush or by dipping in lye. Work may be cleaned

by dipping it into nitric acid which has been diluted with an equal volume

of water. The work should be heated as hot as possible without danger of

melting, as this causes the solder to flow better and secure a much better

hold on the surfaces. Hard solder gives better results than half and half,

but is more difficult to work. It is very important that the soldering iron

be kept at a high heat during all work, otherwise the solder will only

stick to the surfaces and will not join with them.

Sweating is a form of soldering in which the surfaces of the work are first

covered with a thin layer of solder by rubbing them with the hot iron after

it has been dipped in or touched to the soldering stick. These surfaces are

then placed in contact and heated to a point at which the solder melts and

unites. Sweating is much to be preferred to ordinary soldering where the

form of the work permits it. This is the only method which should ever be

used when a fitting is to be placed over the end of a length of tube.

Soldering Holes.—Clean the surfaces for some distance around the

hole until they are bright, and apply flux while holding the hot iron near

the hole. Touch the tip of the iron to some solder until the solder is

picked up on the iron, and then place this solder, which was just picked

up, around the edge of the hole. It will leave the soldering iron and stick

to the metal. Keep adding solder in this way until the hole has been closed

up by working from the edges and building toward the center. After the hole

is closed, apply more flux to the job and smooth over with the hot iron

until there are no rough spots. Should the solder refuse to flow smoothly,

the iron is not hot enough.

Soldering Seams.—Clean back from the seam or split for at least

half an inch all around and then build up the solder in the same way as was

done with the hole. After closing the opening, apply more flux to the work

and run the hot iron lengthwise to smooth the job.

Soldering Wires.—Clean all insulation from the ends to be soldered

and scrape the ends bright. Lay the ends parallel to each other and,

starting at the middle of the cleaned portion, wrap the ends around each

other, one being wrapped to the right, the other to the left. Hold the hot

iron under the twisted joint and apply flux to the wire. Then dip the iron

in the solder and apply to the twisted portion until the spaces between the

wires are filled with solder. Finish by smoothing

the joint and cleaning

away all excess metal by rubbing the hot iron lengthwise. The joint should

now be covered with a layer of rubber tape and this covered with a layer of

ordinary friction tape.

Steel and Iron.—Steel surfaces should be cleaned, then covered with

clear muriatic acid. While the acid is on the metal, rub with a stick of

zinc and then tin the surfaces with the hot iron as directed. Cast iron

should be cleaned and dipped in strong lye to remove grease. Wash the lye

away with clean water and cover with muriatic acid as with steel. Then rub

with a piece of zinc and tin the surfaces by using resin as a flux.

It is very difficult to solder aluminum with ordinary solder. A special

aluminum solder should be secured, which is easily applied and makes a

strong joint. Zinc or phosphor tin may be used in place of ordinary solder

to tin the surfaces or to fill small holes or cracks. The aluminum must be

thoroughly heated before attempting to solder and the flux may be either

resin or soldering acid. The aluminum must be thoroughly cleaned with

dilute nitric acid and kept hot while the solder is applied by forcible

rubbing with the hot iron.

BRAZING

This is a process for joining metal parts, very similar to soldering,

except that brass is used to make the joint in place of the lead and zinc

alloys which form solder. Brazing must not be attempted on metals whose

melting point is less than that of sheet brass.

Two pieces of brass to be brazed together are heated to a temperature at

which the brass used in the process will melt and flow between the

surfaces. The brass amalgamates with the surfaces

and makes a very strong

and perfect joint, which is far superior to any form of soldering where the

work allows this process to be used, and in many cases is the equal of

welding for the particular field in which it applies.

Brazing Heat and Tools.—The metal commonly used for brazing will

melt at heats between 1350° and 1650° Fahrenheit. To bring the parts to

this temperature, various methods are in use, using solid, liquid or

gaseous fuels. While brazing may be accomplished with the fire of the

blacksmith forge, this method is seldom satisfactory because of the

difficulty of making a sufficiently clean fire with smithing coal, and it

should not be used when anything else is available. Large jobs of brazing

may be handled with a charcoal fire built in the forge, as this fuel

produces a very satisfactory and clean fire. The only objection is in the

difficulty of confining the heat to the desired parts of the work.

The most satisfactory fire is that from a fuel gas torch built for this

work. These torches are simply forms of Bunsen burners, mixing the proper

quantity of air with the gas to bring about a perfect combustion. Hose

lines lead to the mixing tube of the gas torch, one line carrying the gas

and the other air under a moderate pressure. The air line is often

dispensed with, allowing the gas to draw air into the burner on the

injector principle, much the same as with illuminating gas burners for use

with incandescent mantles. Valves are provided with which the operator may

regulate the amount of both gas and air, and ordinarily the quality and

intensity of the flame.

When gas is not available, recourse may be had to the gasoline torch made

for brazing. This torch is built in the same way as the small portable

gasoline torches for soldering operations, with the exception that two

regulating needle valves are incorporated in place of only one.

The torches are carried on a framework, which also supports the work being

handled. Fuel is forced to the torch from a large tank of gasoline into

which air pressure is pumped by hand. The torches are regulated to give

the desired flame by means of the needle valves in much the same way as

with any other form of pressure torch using liquid fuel.

Another very satisfactory form of torch for brazing is the acetylene-air

combination described in the chapter on welding instruments. This torch

gives the correct degree of heat and may be regulated to give a clean and

easily controlled flame.

Regardless of the source of heat, the fire or flame must be adjusted so

that no soot is deposited on the metal surfaces of the work. This can only

be accomplished by supplying the exact amounts of gas and air that will

produce a complete burning of the fuel. With the brazing torches in common

use two heads are furnished, being supplied from the same source of fuel,

but with separate regulating devices. The torches are adjustably mounted in

such a way that the flames may be directed toward each other, heating two

sides of the work at the same time and allowing the pieces to be completely

surrounded with the flame.

Except for the source of heat, but one tool is required for ordinary

brazing operations, this being a spatula formed by flattening one end of a

quarter-inch steel rod. The spatula is used for placing the brazing metal

on the work and for handling the flux that is required in this work as in

all other similar operations.

Spelter.—The metal that is melted into the joint is called spelter.

While this name originally applied to but one particular grade or

composition of metal, common use has extended the meaning until it is

generally applied to all grades.

Spelter is variously composed of alloys containing copper, zinc, tin and

antimony, the mixture employed depending on the work to be done. The

different grades are of varying hardness, the harder kinds melting at

higher temperatures than the soft ones and producing a stronger joint when

used. The reason for not using hard spelter in all cases is the increased

difficulty of working it and the fact that its melting point is so near to

some of the metals brazed that there is great danger of melting the work as

well as the spelter.

The hardest grade of spelter is made from three-fourths copper with

one-fourth zinc and is used for working on malleable and cast iron and for

steel.

This hard spelter melts at about 1650° and is correspondingly difficult to

handle.

A spelter suitable for working with copper is made from equal parts of

copper and zinc, melting at about 1400° Fahrenheit, 500° below the melting

point of the copper itself. A still softer brazing metal is composed of

half copper, three-eighths zinc and one-eighth tin. This grade is used for

fastening brass to iron and copper and for working with large pieces of

brass to brass. For brazing thin sheet brass and light brass castings, a

metal is used which contains two-thirds tin and one-third antimony. The

low melting point of this last composition makes it very easy to work with

and the danger of melting the work is very slight. However, as might be

expected, a comparatively weak joint is secured, which will not stand any

great strain.

All of the above brazing metals are used in powder form so that they may be

applied with the spatula where the joint is exposed on the outside of the

work. In case it is necessary to braze on the inside of a tube or any deep

recess, the spelter may be placed on a flat rod long enough to reach to

the farthest point. By distributing the spelter at the proper points along

the rod it may be placed at the right points by turning the rod over after

inserting into the recess.

Flux.—In order to remove the oxides produced under brazing heat and

to allow the brazing metal to flow freely into place, a flux of some kind

must be used. The commonest flux is simply a pure calcined borax powder,

that is, a borax powder that has been heated until practically all the

water has been driven off.

Calcined borax may also be mixed with about 15 per cent of sal ammoniac to

make a satisfactory fluxing powder. It is absolutely necessary to use flux

of some kind and a part of whatever is used should be made into a paste

with water so that it can be applied to the joint to be brazed before

heating. The remainder of the powder should be kept dry for use during the

operation and after the heat has been applied.

Preparing the Work.—The surfaces to be brazed are first thoroughly

cleaned with files, emery cloth or sand paper. If the work is greasy, it

should be dipped into a bath of lye or hot soda water so that all trace of

oil is removed. The parts are then placed in the relation to each other

that they are to occupy when the work has been

completed. The edges to be

joined should make a secure and tight fit, and should match each other at

all points so that the smallest possible space is left between them. This

fit should not be so tight that it is necessary to force the work into

place, neither should it be loose enough to allow any considerable space

between the surfaces. The molten spelter will penetrate between surfaces

that water will flow between when the work and spelter have both been

brought to the proper heat. It is, of course, necessary that the two parts

have a sufficient number of points of contact so that they will remain in

the proper relative position.

The work is placed on the surface of the brazing table in such a position

that the flame from the torches will strike the parts to be heated, and

with the joint in such a position that the melted spelter will flow down

through it and fill every possible part of the space between the surfaces

under the action of gravity. That means that the edge of the joint must be

uppermost and the crack to be filled must not lie horizontal, but at the

greatest slant possible. Better than any degree of slant would be to have

the line of the joint vertical.

The work is braced up or clamped in the proper position before commencing

to braze, and it is best to place fire brick in such positions that it will

be impossible for cooling draughts of air to reach the heated metal should

the flame be removed temporarily during the process. In case there is a

large body of iron, steel or copper to be handled, it is often advisable to

place charcoal around the work, igniting this with the flame of the torch

before starting to braze so that the metal will be maintained at the

correct heat without depending entirely on the torch.

When handling brass pieces having thin sections there is danger of melting

the brass and causing it to flow away from under the flame, with the result

that the work is ruined. If, in the judgment of the workman, this may

happen with the particular job in hand, it is well to build up a mould of

fire clay back of the thin parts or preferably back of the whole piece, so

that the metal will have the necessary support. This mould may be made by

mixing the fire clay into a stiff paste with water and then packing it

against the piece to be supported tightly enough so that the form will be

retained even if the metal softens.

Brazing.—With the work in place, it should be well covered with the

paste of flux and water, then heated until this flux boils up and runs over

the surfaces. Spelter is then placed in such a position that it will run

into the joint and the heat is continued or increased until the spelter

melts and flows in between the two surfaces. The flame should surround the

work during the heating so that outside air is excluded as far as is

possible to prevent excessive oxidization.

When handling brass or copper, the flame should not be directed so that its

center strikes the metal squarely, but so that it glances from one side or

the other. Directing the flame straight against the work is often the cause

of melting the pieces before the operation is completed. When brazing two

different metals, the flame should play only on the one that melts at the

higher temperature, the lower melting part receiving its heat from the

other. This avoids the danger of melting one before the other reaches the

brazing point.

The heat should be continued only long enough to cause the spelter to flow

into place and no longer. Prolonged heating of any metal can do nothing but

oxidize and weaken it, and this practice should be avoided as much as

possible. If the spelter melts into small globules in place of flowing, it

may be caused to spread and run into the joint by lightly tapping the work.

More dry flux may be added with the spatula if the tapping does not produce

the desired result.

Excessive use of flux, especially toward the end of the work, will result

in a very hard surface on all the work, a surface which will be extremely

difficult to finish properly. This trouble will be present to a certain

extent anyway, but it may be lessened by a vigorous scraping with a wire

brush just as soon as the work is removed from the fire. If allowed to cool

before cleaning, the final appearance will not be as good as with the

surplus metal and scale removed immediately upon completing the job.

After the work has been cleaned with the brush it may be allowed to cool

and finished to the desired shape, size and surface by filing and

polishing. When filed, a very thin line of brass should appear where the

crack was at the beginning of the work. If it is desired to avoid a square

shoulder and fill in an angle joint to make it rounding, the filling is

best accomplished by winding a coil of very thin brass wire around the part

of the work that projects and then causing this to flow itself or else

allow the spelter to fill the spaces between the layers of wire. Copper

wire may also be used for this purpose, the spaces being filled with

melted spelter.

THERMIT WELDING

The process of welding which makes use of the great heat produced by oxygen

combining with aluminum is known as the Thermit process and was perfected

by Dr. Hans Goldschmidt. The process, which is controlled by the

Goldschmidt Thermit Company, makes use of a mixture of finely powdered

aluminum with an oxide of iron called by the trade name, Thermit.

The reaction is started with a special ignition powder, such as barium

superoxide and aluminum, and the oxygen from the iron oxide combining with

the aluminum, producing a mass of superheated steel at about 5000 degrees

Fahrenheit. After the reaction, which takes from. 30 seconds to a minute,

the molten metal is drawn from the crucible on to the surfaces to be

joined. Its extreme heat fuses the metal and a perfect joint is the result.

This process is suited for welding iron or steel parts of comparatively

large size.

Preparation.—The parts to be joined are thoroughly cleaned on the

surfaces and for several inches back from the joint, after which they are

supported in place. The surfaces between which the metal will flow are

separated from ¼ to 1 inch, depending on the size of the parts, but

cutting or drilling part of the metal away. After this separation is made

for allowing the entrance of new metal, the effects of contraction of the

molten steel are cared for by preheating adjacent parts or by forcing the

ends apart with wedges and jacks. The amount of this last separation must

be determined by the shape and proportions of the parts in the same way as

would be done for any other class of welding which heats the parts to a

melting point.

Yellow wax, which has been warmed until plastic, is then placed around the

joint to form a collar, the wax completely filling the space between the

ends and being provided with vent holes by imbedding a piece of stout cord,

which is pulled out after the wax cools.

A retaining mould (Figure 55) made from sheet steel or fire brick is then

placed around the parts. This mould is then filled with a mixture of one

part fire clay, one part ground fire brick and one part fire sand. These

materials are well mixed and moistened with enough water so that they will

pack. This mixture is then placed in the mould, filling the space between

the walls and the wax, and is packed hard with a rammer so that the

material forms a wall several inches thick between any point of the mould

and the wax. The mixture must be placed in the mould in small quantities

and packed tight as the filling progresses.
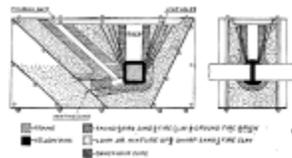
Image Figure 55.—Thermit Mould Construction

Three or more openings are provided through this moulding material by the

insertion of wood or pipe forms. One of these openings will lead from the

lowest point of the wax pattern and is used for the introduction of the

preheating flame. Another opening leads from the top of the mould into this

preheating gate, opening into the preheating gate at a point about one inch

from the wax pattern. Openings, called risers, are then provided from each

of the high points of the wax pattern to the top of the mould, these risers

ending at the top in a shallow basin. The molten metal comes up into these

risers and cares for contraction of the casting,

as well as avoiding

defects in the collar of the weld. After the moulding material is well

packed, these gate patterns are tapped lightly and withdrawn, except in the

case of the metal pipes which are placed at points at which it would be

impossible to withdraw a pattern.

Preheating.—The ends to be welded are brought to a bright red heat

by introducing the flame from a torch through the preheating gate. The

torch must use either gasoline or kerosene, and not crude oil, as the crude

oil deposits too much carbon on the parts. Preheating of other adjacent

parts to care for contraction is done at this time by an additional torch

burner.

The heating flame is started gently at first and gradually increased. The

wax will melt and may be allowed to run out of the preheating gate by

removing the flame at intervals for a few seconds. The heat is continued

until the mould is thoroughly dried and the parts to be joined are brought

to the red heat required. This leaves a mould just the shape of the wax

pattern.

The heating gate should then be plugged with a sand core, iron plug or

piece of fitted fire brick, and backed up with several shovels full of the

moulding mixture, well packed.
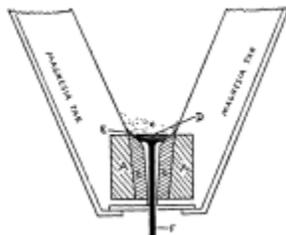
Image Figure 56.—Thermit Crucible Plug.

A, Hard burn magnesia stone;

B, Magnesia thimble;

C, Refractory sand;

D, Metal disc;

E, Asbestos washer;

F, Tapping pin

Thermit Metal.—The reaction takes place in a special crucible lined

with magnesia tar, which is baked at a red heat until the tar is driven off

and the magnesia left. This lining should last from twelve to fifteen

reactions. This magnesia lining ends at the bottom of the crucible in a

ring of magnesia stone and this ring carries a magnesia thimble through

which the molten steel passes on its way to the mould. It will usually be

necessary to renew this thimble after each reaction. This lower opening is

closed before filling the crucible with thermit by means of a small disc or

iron carrying a stem, which is called a tapping pin (Figure 56). This pin,

F, is placed in the thimble with the stem extending down through the

opening and exposing about two inches. The top of this pin is covered with

an asbestos, washer, E, then with another iron disc. D, and

finally with a layer of refractory sand. The crucible is tapped by knocking

the stem of the pin upwards with a spade or piece of flat iron about four

feet long.

The charge of thermit is added by placing a few handfuls over the

refractory sand and then pouring in the balance required. The amount of

thermit required is calculated from the wax used. The wax is weighed before

and after filling the entire space that the thermit will occupy.

This does not mean only the wax collar, but the space of the mould with all

gates filled with wax. The number of pounds of wax required for this

filling multiplied by 25 will give the number of pounds of thermit to be

used. To this quantity of thermit should be added I per cent of pure

manganese, 1 per cent nickel thermit and 15 per cent of steel punchings.

It is necessary, when more than 10 pounds of thermit will be used, to mix

steel punchings not exceeding 3/8 inch diameter by 1/8 inch thick with the

powder in order to sufficiently retard the intensity of the reaction. Half a teaspoonful of ignition powder is placed on top of the thermit charge and ignited with a storm match or piece of red hot iron. The cover

should be immediately closed on the top of the crucible and the operator

should get away to a safe distance because of the metal that may be thrown

out of the crucible.

After allowing about 30 seconds to a minute for the reaction to take place

and the slag to rise to the top of the crucible, the tapping pin is struck

from below and the molten metal allowed to run into the mould. The mould

should be allowed to remain in place as long as possible, preferably over

night, so as to anneal the steel in the weld, but in no case should it be

disturbed for several hours after pouring. After removing the mould, drill

through the metal left in the riser and gates and knock these sections off.

No part of the collar should be removed unless absolutely necessary.

CHAPTER IX

OXYGEN PROCESS FOR REMOVAL OF CARBON

Until recently the methods used for removing carbon deposits from gas

engine cylinders were very impractical and unsatisfactory. The job meant

dismantling the motor, tearing out all parts, and scraping the pistons and

cylinder walls by hand.

The work was never done thoroughly. It required hours of time to do it, and

then there was always the danger of injuring the inside of the cylinders.

These methods have been to a large extent superseded by the use of oxygen

under pressure. The various devices that are being manufactured are known

as carbon removers, decarbonizers, etc., and large numbers of them are in

use in the automobile and gasoline traction motor industry.

Outfit.—The oxygen carbon cleaner consists of a high pressure

oxygen cylinder with automatic reducing valve, usually constructed on the

diaphragm principle, thus assuring positive regulation of pressure. This

valve is fitted with a pressure gauge, rubber hose, decarbonizing torch

with shut off and flexible tube for insertion into the chamber from which

the carbon is to be removed.

There should also be an asbestos swab for swabbing out the inside of the

cylinder or other chamber with kerosene previous to starting the operation.

The action consists in simply burning the carbon to a fine dust in the

presence of the stream of oxygen, this dust being then blown out.

Operation.—The following are instructions for operating the

cleaner:--

(1) Close valve in gasoline supply line and start the motor, letting it run

until the gasoline is exhausted.

(2) If the cylinders be T or L head, remove either the inlet or the exhaust

valve cap, or a spark plug if the cap is tight. If the cylinders have

overhead valves, remove a spark plug. If any spark plug is then remaining

in the cylinder it should be removed and an old one or an iron pipe plug

substituted.

(3) Raise the piston of the cylinder first to be

cleaned to the top of the

compression stroke and continue this from cylinder to cylinder as the work

progresses.

(4) In motors where carbon has been burned hard, the cylinder interior

should then be swabbed with kerosene before proceeding. Work the swab,

saturated with kerosene, around the inside of the cylinder until all the

carbon has been moistened with the oil. This same swab may be used to

ignite the gas in the cylinder in place of using a match or taper.

(5) Make all connections to the oxygen cylinder.

(6) Insert the torch nozzle in the cylinder, open the torch valve gradually

and regulate to about two lbs. pressure. Manipulate the nozzle inside the

cylinder and light a match or other flame at the opening so that the carbon

starts to burn. Cover the various points within the cylinder and when there

is no further burning the carbon has been removed. The regulating and

oxygen tank valves are operated in exactly the same way as for welding as

previously explained.

It should be carefully noted that when the piston is up, ready to start the

operation, both valves must be closed. There will be a considerable display

of sparks while this operation is taking place, but they will not set fire

to the grease and oil. Care should be used to see that no gasoline is

about.

INDEX

Acetylene

filtering

materials
practice, oxy-acetylene
rods
spot
steel
table
thermit
torches
various metals
wrought iron
Wrought iron
welding

Zinc