Autogenous Welding of Metals

Translated from Reports of the National School of Arts and Trades of France

By L. L. BERNIER, M.E.

ILLUSTRATED

NEW YORK
THE BOILER MAKER
17 Battery Place
1908

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A description of the application of Autogenous Welding to the manufacture of Tanks; Gasometers, Receptacles for Liquids or Gases, with or without pressure; Steam and Hot Water Boilers, Kettles; Small Boats; Automobiles; Piping, either steel, copper or brass; and Coils of all kinds; and also its application to Repairing old or new Castings injured through such defects as blow-holes, cracks, etc. Its application to the Manufacture of Steel, Brass, Bars and Plates, and to the Destruction of Metals, Structures, etc.

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CHAPTER I.

HIGH TEMPERATURES FOR INDUSTRIAL PURPOSES OBTAINED BY MEANS OF BURNERS.

DEFINITIONS.

The so-called oxyacetylene welding of metals consists in the assembling, by means of more or less complete melting of metallic pieces of the same nature, the surfaces of which are brought in contact at a high temperature, without interposition of a different metal from that constituting the pieces.

By extension, the name "oxyacetylene" has been applied to welding made between pieces of different metals which can, however, form a resisting alloy. On the other hand, the interposition of another neutral metal capable of forming a more or less perfect assembling between the two similar or different metals in presence constitutes a "brazing," and tin soldering is among that class.

The melting points of the various metals being very different, the oxyacetylene welding of a certain number of metals (lead, for instance) has been easily accomplished for a number of years, while its application to iron, steel, brass, etc., has been more difficult and required entirely different processes.

We shall consider these latter processes only, and if we were to refer to the definition of oxacetylene welding we would have to establish the following classification:

Welding with a blacksmith's forge.

Hydrothermal welding.
Electrical welding.
Oxyhydric blow-pipe.
Oxyacetylenic blow-pipe.
Illuminating gas and oxygen blow-pipe.

However, the processes using gas burners affording numerous advantages to the ordinary work of the various industries, only the following processes are actually to be considered:

Oxyhydric burner (oxygen and hydrogen).
Oxyacetylenic burner (oxygen and acetylene).
Oxygas burner (oxygen and illuminating gas).

COMPARISON BETWEEN THE VARIOUS TYPES OF BLOW-PIPES.

The oxygen and hydrogen used in the oxyhydric burner may be obtained from the tanks in general use in the trade, in which these gases are compressed under a pressure of 300 to 1,800 pounds per square inch. They may also be generated on the spot by the electrolysis of water, and then compressed under a pressure of 300 pounds, to be then distributed to the burners through appropriate pipe lines.

In general, this latter principle is not applied because of the costly apparatus, the experienced personnel and the expensive maintenance which it requires. Moreover, the decomposition of the water into its elements and the fact that the hydrogen and oxygen pipe lines must of necessity run close to each other, constitute a source of danger and render impossible the production of these gases in the consumer's plant.

As a rule all the oxyhydric burners in use are supplied from ordinary tanks containing the gases under pressure. The actual average prices are: oxygen, 4 cents per cubic foot; hydrogen, about 1 cent per cubic foot.

For oxyacetylenic burners commercial oxygen is used; the acetylene comes from one of the following sources: Dissolved acetylene in tanks, where the gas is dissolved in acetone, impregnating a porous material and under an average pressure of 150 pounds; acetylene generating apparatus, producing the gas on the spot under a pressure of about 10 pounds whenever required. The actual average prices are as follows: Oxygen, 4 cents per cubic foot; dissolved acetylene, 2 cents per cubic foot. The cost price of acetylene produced on the spot by generating apparatus is about 1 cent per cubic foot.

Oxygas blow-pipes are supplied with ordinary commercial coal gas from the distributing pipes of special tanks. In the following calculations illuminating gas has been reckoned at the rate of $1.25 per thousand cubic feet:

	Oxyacetylene Mixture.	Oxyhydric Mixture.	Oxygas Mixture.
Temperature obtained by complete combustion of the mixture about	6,219°	4,156°	3,132°
Number of B. T. U. obtained by complete combustion of 1 cubic foot of combustible gas.	1,570.	290.	616.
Quantity of pure oxygen theoretically necessary for the complete combustion of 1 cubic foot of combustible gas.cu. ft.	2.510	0.620	0.923
Quantity of pure oxygen fed to the blow-pipe per cubic foot of combustible gas (results of experiments).........cu. ft.	1.300	0.250	0.670
Respective quantities of the gases to be fed to the blow-pipe to obtain 1,000 B. T. U. cu. ft.	A .666 O .866	H 3.846 O .96	G 1.81 O 1.21
Cost price of 1,000 B. T. U. (according to above prices):			
Dissolved Ac............cts.	4.797		
Generator Ac...........cts.	4.13	7.69	5.066

The above figures will be very useful in making comparisons hereafter.

From the point of view of their use the oxyacetylene welding processes may be classified as follows:

Processes admitting of the easy transportation of the welding apparatus to the places where the work is to be done; dissolved acetylene welding; oxyhydric welding.

Processes necessitating the transportation of the piece to be welded to a fixed welding station; oxyacetylene welding, the acetylene being supplied by a generator; illuminating gas welding.

PORTABLE OXYACETYLENE WELDING APPARATUS. DISSOLVED ACETYLENE. OXYHYDRIC.

(*a*) *Comparative Cost Prices of the Two Systems.*

The cost price of 1,000 B. T. U. can easily be established, knowing the price of the gases used and the quantity of practically pure oxygen fed to the blow-pipe for the combustion of 1 cubic foot of combustible. Figuring on 4 cents per cubic foot for oxygen, 1 cent per cubic foot for hydrogen, and 2 cents for dissolved acetylene per cubic foot, it will be found that 1,000 B. T. U. (acetylenic, dissolved acetylene) cost 4.797 cents; 1,000 oxyhydric B. T. U. cost 7.69 cents.

But the cost of workmanship must also be taken into account in the fixing of the cost price of the welding. In consequence of the lower temperature of the oxyhydric mixture the time required to melt the metal is naturally longer with this process than with the acetylene, and the result is that for a given amount of work the cost of workmanship is higher. The following curves (Fig. 1 and 2), obtained from the results of numerous trials, clearly show this difference.

The superiority of each one of the constituting elements of the cost price of the acetylenic mixture over that of the oxyhydric mixture is also apparent, and, greater still, in the total of this price. Thus experience has shown that the cost of welding sheet metal of ¾ inch thickness by the dissolved acetylene process is only half of that of the oxyhydric mixture.

(*b*) *Comparison of the Two Processes from the Points of View of Easiness of Handling and Applications.*

When buying an apparatus, however good and economical its principle may be, it is very important to consider the question of how easily the necessary force of men will be trained to its use, and to be able to indicate the well-defined mode of its regulating. In the oxyacetylene process of welding, more

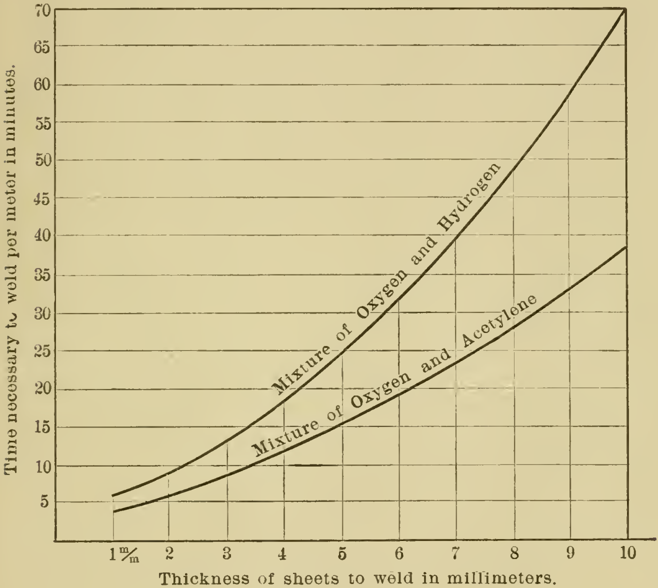


FIG. 1.

than in anything else, the regulating is of supreme importance, as the quality of the finished work is essentially dependent on it, because an excess of either the combustible or of the supporter of combustion may cause an alteration of the metal and its properties.

In the course of a recent dispute the partisans of the oxyhydric mixture announced the opinion that the oxyacetylene blow-pipe produced brittle welds. The inaccuracy of this

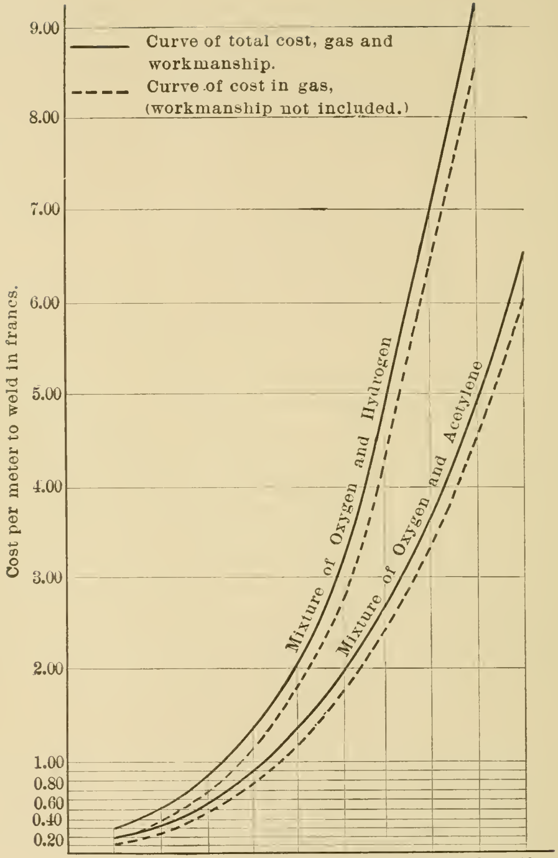

Curve of total cost, gas and workmanship.
Curve of cost in gas, (workmanship not included.)
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.80
0.60
0.40
0.20
Cost per meter to weld in francs.
Mixture of Oxygen and Hydrogen
Mixture of Oxygen and Acetylene
1 m/m
2
3
4
5
6
7
8
9
10
Thickness of sheets to weld in millimeters.

FIG. 2.

assertion was demonstrated, particularly at the Society of the Civil Engineers of France (see official report of the meeting of March 16, 1906), and with the corroboration of extensive actual trials it had to be admitted that the oxyacetylenic as well as the oxyhydric mixture gave perfect results, the defects noted with one or the other systems being due to a defective regulation of the flame.

The combustion of the oxyhydric mixture produces a flame of very small illuminating power, the purple and red color of which it is almost impossible to describe. In the proportions required to obtain a perfect weld, the flame of the oxyacetylenic mixture is characterized by a white central part very neatly outlined, surrounded by an almost colorless flame. The least variation in the proportion of the combustible gas and the gas supporting the combustion, immediately modifies the shape and the color of this central part, noticeable even to the most inexperienced eye. This remarkable property of the oxyacetylenic flame is applied to the regulating of the blow-pipes, and enables anybody to discover at a glance the proper or defective composition of the mixture.

Unfortunately, this sure and practical method of regulating cannot be applied to the oxyhydric mixture, which has no well defined characteristic flame, and the excess of one or the other gases causing variations of color that the eye cannot detect. Undoubtedly, at first, the oxyhydric blow-pipe, placed into the hands of a few very smart workmen, enabled them to practically obtain excellent results. But as its use became more general it was very soon found that in a number of cases there was no welding, but simply that two damaged parts of metal were merely stuck together. The problem to be solved was the automatic supply of the gases in the required proportion: the high pressure under which the tanks were filled when put into service had to be taken into account, as also the decrease of said pressure in the course of the consumption of gas; and, finally, the variable flow required.

In the instruments then invented a regulating valve was set in motion through the elasticity of reciprocating parts and springs. This valve was raised only a few tenths of a millimeter, and its almost capillary orifice was subject to frequent partial obstructions. The working of such systems is most uncertain, and the results obtained are by no means up to the expectations. At the present time the problem has not as yet been solved, and this difficulty of regulating the flame is certainly one of the reasons which retard the development of oxyhydric welding.

The temperature of 6,000 degrees, produced by the oxyacetylene blow-pipe, was at first considered as an inconvenience by those who thought that the metal to be soldered would itself reach that temperature, which was much higher than its melting point, and that its properties would consequently be altered. But this criticism is absolutely without foundation, because when welding the metal is not in the same condition as if it were in a furnace subjected to the action of the blow-pipe, and the melting part, being in contact with a part that is not yet melted, has not the same temperature as the flame. In the case of a metal plate, for instance, if the action of the blow-pipe is kept up longer than is necessary, the melted metal falls in drops, making a hole in the plate, but its temperature is not raised considerably over the melting point. The 6,000 degrees for which the acetylene blow-pipe was blamed was, on the other hand, used by the acetylenists as an argument in its favor. The quickness in reaching the melting point renders possible the welding of thick plates and pieces of great bulk, such as steel castings. This cannot be done with the oxyhydric blow-pipe, which does not cause the melting of the metal on account of the low temperature of its flame, and of the greater relative losses of heat by conductibility which are the result thereof. The oxyacetylene blow-pipe, by its rapid action, reduces to a minimum the heating of the parts adjoining the weld, and with it close brazings and many other repairs may be made that would otherwise be rendered impossible by the extensive softening of the metal under the slower action of other processes.

Experience shows that for the average thickness of ¼ inch to ¾ inch the welding operation that can be performed with a 50 cubic foot tank of liquid acetylene (weighing 55 pounds), and a 70 cubic foot tank of oxygen (weighing 50 pounds), will require at least 495 cubic feet of hydrogen and 125 cubic feet of oxygen by the oxyhydric process, or four tanks of hydrogen weighing 90 pounds each and one 55-pound tank of oxygen. In other words, where a 105-pound oxyacetylene apparatus will do the work without any taking apart of pieces, a 415-pound oxyhydric installation will be necessary, and will require the hydrogen injector to be taken off and put back three times and the oxygen injector once.

In cases where the metallurgical plants are not near to the establishments producing the gases required it will be necessary, in the selection of the apparatus, to take into account the important difference in the number of B. T. U. obtained per cubic foot of material which exists between the oxyacetylene and oxyhydric processes, and which considerably affects the cost price of welding through the cost of transportation of the tanks.

(*c*) *Conclusions.*

On the whole, the dissolved acetylene process, while on an equal footing with the oxyhydric process in point of expense of installation and maintenance, is very superior from the following points of view, which are the only ones to be considered in ordinary work:

$$\left.\begin{array}{l}\text{Price of the gases used.}\\ \text{Cost of workmanship.}\\ \text{Cost of transportation.}\end{array}\right\}\text{Production being equal.}$$

Easy regulation of the flame.

Ability to weld large pieces.

On the other hand, the oxyhydric process is to be preferred to the oxyacetylene method in the welding of very thin plates (less than 1/32 inch), which requires less ability on the part of the workman, because its action is not as rapid, the fusing speed of the mixture not as high. This speed, indeed, with an oxyacetylene blow-pipe operated by an inexperienced man, may cause holes in the piece that is being welded, which, however, it is easy to repair.

1st. Oxyacetylene supplied by a generator.

2d. Oxygas—Illuminating gas supplied by the ordinary distributing pipes.

(*a*) *Comparative Cost Prices of Both Systems.*

A preceding table has shown that the cost price of 1,000 B. T. U. obtained by what shall hereafter be termed "generator acetylene," is 4.13 cents, while the cost price of 1,000 oxygas B. T. U. is 5.066 cents, taking as a basis the following prices: Acetylene, 2 cents per cubic foot; illuminating gas, $1.25 per 1,000 cubic feet; oxygen, 4 cents per cubic foot.

The two following diagrams, Nos. 3 and 4, show the results of many experiments and the economy of the oxyacetylene mixture.

(*b*) *Comparison Between the Two Processes from the Points of View of Easy Handling and Applications.*

The oxyacetylene flame is undoubtedly much easier to regulate than that of illuminating gas; however, with practice the oxygen flame can be regulated. For this reason we shall not take into account the more or less easy regulating of the flame, as we have done in comparing the oxyhydric and oxyacetylene mixtures.

The oxygas welding can, of course, only be used in cities where there are coal-gas plants. On the contrary, the oxyacetylene welding may be installed anywhere.

The expense of installing an acetylene welding plant is necessarily greater than in the case of coal gas, owing to the price of the generator, which is not to be considered in the case of a coal-gas plant.

This advantage of coal gas is counterbalanced by the inconveniences resulting from the low temperature and the great volume of the flame: impossibility of practically welding thicknesses of 1/6 to 1/5 inch, considerable losses of heat through radiation, which, for ⅛ inch thickness, are a great hindrance to the workman.

Besides, it must be remembered that coal gas for illuminat-

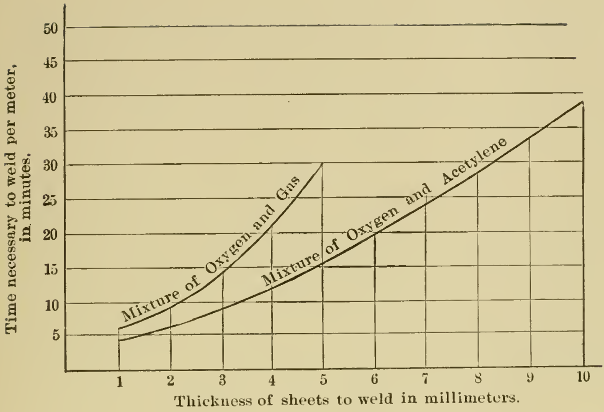

Time necessary to weld per meter, in minutes.
50
45
40
35
30
25
20
15
10
5
Mixture of Oxygen and Gas
Mixture of Oxygen and Acetylene
1
2
3
4
5
6
7
8
9
10
Thickness of sheets to weld in millimeters.

Fig. 3

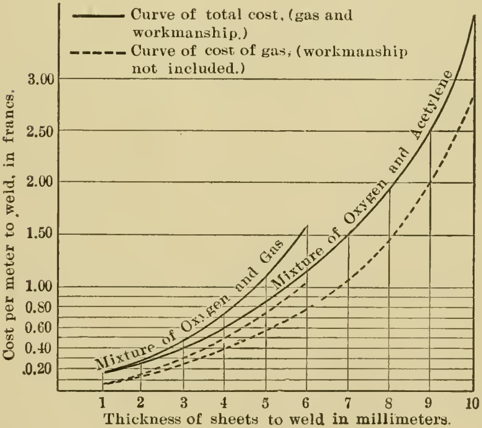

Curve of total cost, (gas and workmanship.)
Curve of cost of gas, (workmanship not included.)
Cost per meter to weld, in francs.
3.00
2.50
2.00
1.50
1.00
0.80
0.60
0.40
.0.20
Mixture of Oxygen and Gas
Mixture of Oxygen and Acetylene
1
2
3
4
5
6
7
8
9
10
Thickness of sheets to weld in millimeters.

Fig. 4

ing purposes contains many impurities, very variable in nature in consequence of the combustibles used in its manufacture. These impurities have a great influence on the quality of the work, and are such as to preclude the certainty that the welds made by this process will withstand any pressure, even if the greatest caution is observed.

(*c*) *Conclusions.*

On the whole, and if the above curves of cost prices are taken in consideration, the oxyacetylene process is more advantageous than the oxygas, except, however, as regards the cost of installation. Hence the oxygas process should only be preferred to oxyacetylene in cases where the cost of installation has to be taken into account, where the plates to be united are not thicker than 1/6 to 1/5 inch, and where the quality of the weld obtained is of secondary importance only.

CONCLUSIONS.

The above has shown the advantages, in portable apparatus, of dissolved acetylene over hydrogen, and in stationary apparatus, of generator acetylene over coal gas.

When should "pressure" acetylene or "generator" acetylene be used?

It is evident that liquid acetylene imposes itself in all cases where the possession of a portable apparatus is necessary for work outside of the shop, or in the shop on pieces difficult to handle, and also when the work to be done is of short duration.

The smaller initial expense and the easy, perfect control of the consumption are also in favor of dissolved acetylene for experiments, studies and regulation of new manufactures.

On the other hand, the cost price of the work will become the most important factor in steady manufactures, and preference will then be given to generator acetylene, if the plant has enough room for the installation of the generator.

The generator will also be available in shops not provided with a practical system of lighting, or if acetylene is desired as an emergency system of illumination, as, for instance, when the motors are out of commission in shops electrically lighted.

CHAPTER II.

DESCRIPTION OF OXYACETYLENE WELDING PLANTS.

With reference to the various parts of the apparatus the welding installations may be grouped in two classes:

1st. The combustible gas and the gas supporting the combustion enter the blow-pipe under rather high pressures (in general 7 to 15 pounds per square inch), in order to insure to each sufficient velocity at the mouth of the pipe. This refers to the following installations: Oxyhydric, dissolved acetylene and generator acetylene under pressure.

2d. One of the gases, generally the combustible, is obtained from a source where the pressure is only a few ounces, and the other gas must flow under a pressure sufficient to draw out the first and insure a proper velocity to the mixture at the mouth of the blow-pipe. Such are the installations of oxygas and generator acetylene without pressure.

INSTALLATIONS USING BOTH GASES UNDER PRESSURE.

In this class we can make two sub-divisions:

(*a*) Both gases come from tanks where their pressure is higher than that needed in the blow-pipe (oxyhydric and dissolved acetylene apparatus).

(*b*) One of the gases is produced under a pressure nearly equal to that in the blow-pipe (oxyacetylene under pressure from generator).

(*a*) *Oxyhydric and Dissolved Acetylene Apparatus.*

The hydrogen and oxygen used in these processes come from seamless steel tanks, in which they are under a pressure of 150 pounds per square inch. The acetylene is contained in steel tanks, completely filled with a porous matter soaked in acetone, in which the gas is dissolved under a convenient saturation pressure of about 150 pounds per square inch.

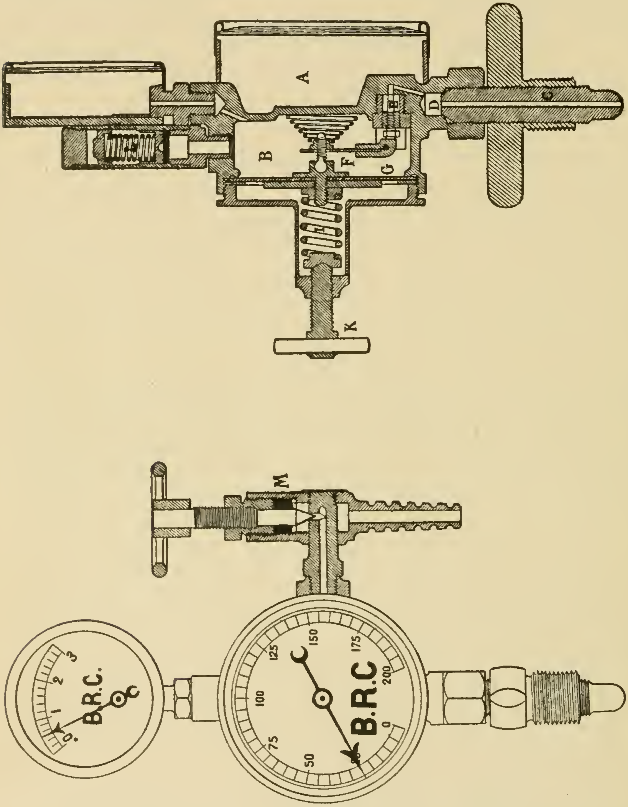


FIG. 5.

These gases, to be used in the blow-pipe, must therefore be brought to a lower pressure; this result is attained by the use of regulating valves mounted on the tanks. In the actual work these regulating valves are used in conjunction with gages, constantly indicating the pressure of the gas in the tank, and consequently how much gas is left in it.

The various valves and gages used for oxygen, hydrogen and dissolved acetylene are almost similar, and differ only in the metal of which they are made, but their principle is the same.

The instrument, Fig. 5, described below is composed of a cylindrical box divided in two parts. In one of them *A* is the gage, in the other *B* the regulating valve. The gas coming by a tube *C* passes through a chamber *D* lined with a filtering matter, stopping the dust that might be driven in by the gas; this chamber has two orifices; one in connection with the gage tube, the other, incompletely closed by a needle point *E,* and through which passes the gas going into the expansion chamber. On this needle point *E* rests a lever *F* connected with the center of an elastic diaphragm *G.*

Under this diaphragm is a spring which constantly maintains the needle point in close contact with its seat when the pressure on top of the diaphragm is equal to the atmospherical pressure without regard to the pressure of the gas in the tank. On top of the diaphragm is a second spring *I,* the tension of which is regulated at will by means of a screw *K.* Under normal working conditions the pressure of the gas on the diaphragm and the pressure of the spring counterbalance each other. It follows that the pressure of the expanded gas depends only on the tension of the spring, and is independent —or nearly so—of the variation of pressure in the flask.

A safety valve *L* placed on the expansion chamber limits the pressure in that chamber to a maximum, which a defective working of the needle point *E* might tend to exceed. A needle point cock *M,* placed at the end of this chamber, connects the regulating valve and the blow-pipe, and is used to stop the flow of gas at any time without being compelled to close the cock of the tank itself.

Emanating from the regulating valves, the gases are brought through rubber tubes of convenient diameter to the blow-pipe, where the mixture takes place, to be ignited at the mouth.

In the type of installations now discussed both the combustible gas and the supporter of combustion arrive in the blow-pipe under very nearly equal pressures sufficient to insure a speed of the mixture at the mouth of the blow-pipe slightly greater than that of the spreading of the flame through this mixture. Under these conditions, if the working of the apparatus was regular and perfect, there would be no fear of a back draft inside of the blow-pipe. Relying on this theoretical impossibility of a back draft, under normal working conditions, a number of manufacturers offered, until very recently, oxyhydric blow-pipes having no safety appliances to

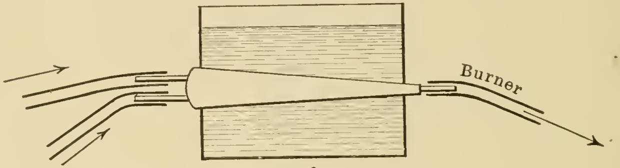


FIG. 6.

avoid a return of the flame inside of the apparatus. But if for any reason (defective working of a regulating valve, insufficient pressure in a tank, smashing or folding of a rubber hose, contact of the end of the blow-pipe with the pipe to be welded, etc.) the speed at the mouth became for an instant inferior to that practically necessary, the blow-pipe became red hot, burning the workman's hand, and the flame ran back as far as the rubber tubes, which were burned; the valves had to be instantly closed and everything put in shape again.

In the oxacetylene blow-pipe of the Dissolved Acetylene Company the safety appliance is located inside of the apparatus; the back draft is avoided by a particular construction, by which the mixture of acetylene and oxygen convenient for the welding flame takes place in a very small space near the mouth of the blow-pipe. From this mouth to the source of the gases the quantity of acetylene in the mixture decreases. The explosive wave, coming in contact with parts of gas of decreasing explosive power, slackens rapidly. The result is a very reduced localization of back drafts. This appliance is also completed by the interposition, in the supply pipe of acetylene, of a porous screen, which effectively stops the flame, a result that could not be obtained by a cushion of wire gauze, contrary to general belief.

(*b*) *Oxacetylene Installations with Generator Producing Acetylene Under a Pressure of About 7½ Pounds.*

The blow-pipes employed in this case may be simply mixers of gas, as above, with the condition, however, that the pressure of the acetylene supplied by the generator be sufficient to insure to the mixture a speed at the mouth superior to that of the spreading of the flame (a condition which is generally realized in these instruments). But the installation is, however, different from the others. If we suppose that for some reason one of the gases, through an excess of pressure, has a tendency to enter the flask containing the other gas, it is easy to understand, by referring to the description of the above regulating valves and manometers, that the construction of this apparatus renders impossible the connection of one of the tanks with the other.

In the case of installations with generator producing acetylene under a pressure of 7½ pounds the acetylene regulating valve and manometer do not exist, and nothing would stop the oxygen coming out of its tanks to get into the acetylene generator. In order to avoid this possibility of accident it is necessary to interpose in the acetylene pipe, between the blowpipe and the generator, a safety hydraulic interrupter. (See *Technologic Bulletin*, December, 1903, page 1,348.)

INSTALLATIONS USING ONE OF THE GASES TO DRAW OUT THE OTHER.

The acetylene produced by ordinary generators for lighting purposes and the coal gas distributed in the cities are under a pressure of only a few ounces of water.

The oxygen always comes from tanks where its pressure is 150 pounds per cubic foot.

A regulating valve and manometer, placed on the oxygen tank, reduce the pressure of this gas to 15 pounds, under which it is fed to the blow-pipe. The latter is provided with an injector, the diameter of which changes according to the quantities of oxygen required. The oxygen, acting as motor, brings the combustible gas in, and in this way it is possible to

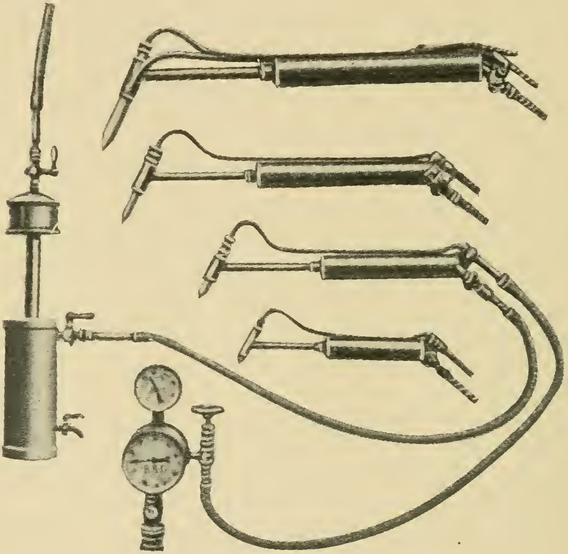


FIG. 8.

regulate the speed of the flame. This is the principle of all the blow-pipes of this class, the difference consisting of more or less perfect details of manufacture.

The first blow-pipe using acetylene without pressure has been invented by Mr. Ed. Fouché (August, 1877).

On account of the considerable difference between the pressures of the oxygen and the combustible gas, and in order to avoid a flowing back of the oxygen in the pipes of the combustible through any accident, it is necessary to interpose on these pipes, and as near the welding point as possible,. an

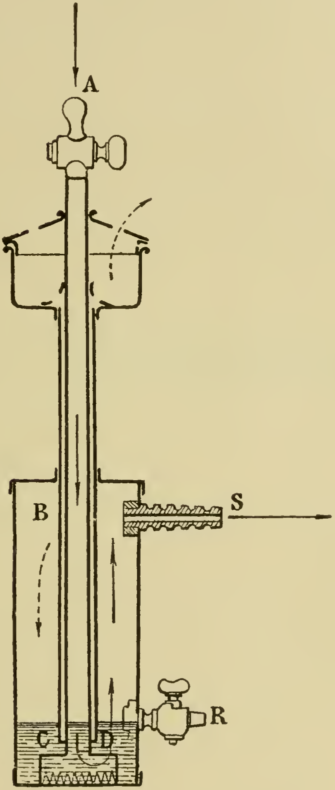


FIG. 8.

hydraulic safety valve. This appliance, Fig. 8, is composed of a central tube *A* for the combustible gas, terminated at its lower extremity by a bell-shaped casting, on the circumference of which are numerous holes through which the gas escapes, reaching the blow-pipe through the tube *S*. The valve chamber is filled with water to the level of a gage cock *R*, and is also provided with a safety tube *B*, the lower end of which is slightly below the normal water level. The top is connected with a basin communicating with the air outside by holes in the cover.

In case of an accidental flowing back of the oxygen in the apparatus, the water rises in the tubes *A* and *B*, and the section *CD* of the safety tube *B* is uncovered; the gas escaping outside and no flowing back can occur in the central tube, which remains immersed in water.

The water carried away is collected in the upper basin, and falls back to the bottom.

BLOW-PIPES.

As previously said, all the blow-pipes used in these kinds of installations are identical as to principle, the only difference between them being the details of manufacture, rendering their working more or less perfect and their manipulation more or less safe.

The safety appliance placed on the acetylene pipe, avoiding all back drafts of the flame, is one of the most important parts of the welding tools.

The French company for the dissolved acetylene process uses a porous material. In the Fouché system the acetylene goes through a series of very long and very thin tubes. In other cases an accumulation of metallic gauzes is resorted to, which is more dangerous than efficacious, and others solve the problem by the complete absence of the safety appliance.

Although it is not our intention to describe the various systems of blow-pipes, we shall draw attention to two systems, still unknown because they are very new.

1st. Warming up of the gaseous mixture before its inflammation.

The insufficient temperature of combustion of coal gas led to appliances for heating it. The company using the compressed gases, to attain this end, warms up the oxygas mixture by means of a flame, bringing to red heat a coil through which the mixture passes. It is evident that this disposition insures a higher temperature of combustion, but its slow action speaks against it. At the moment of lighting, the coil is cold, and the heater has no action on the mixture; its action is only progressive, following the warming up of the coil, so that this disposition is only interesting in cases where the blow-pipe must work without stopping for a long time. This disposition is of no value in the works necessitating the lighting of the blow-pipe for only short periods.

2d. Blow-pipes with interchangeable heads for various sizes of flame. To facilitate the work, and to reduce the consump-

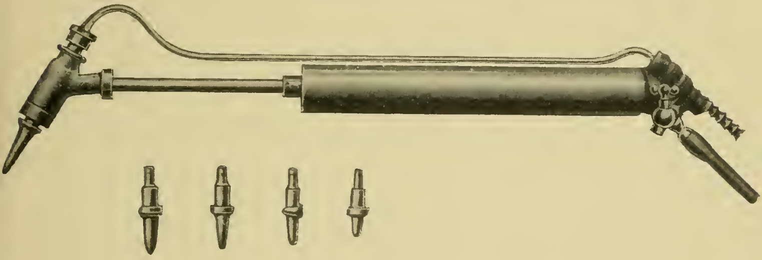


FIG. 9.

tion of gas to a minimum, it is necessary to use blow-pipes giving a flow of gas in proportion to the work to be done. In the case of a blow-pipe where one gas brings in the other, the sections of the injector and of the pipes for the gas carried in, the shape, the sections, and the length of the mixing and egress chambers must be well determined for a given flow. The result is the necessity of making a blow-pipe for each of the necessary flows. Undoubtedly, certain manufacturers have pretended that they obtained flames of different volumes, in which the mixture of the gases was perfect, with the same blow-pipe, the same injector, the same mixing parts, by simply changing the mouth of the blow-pipe. This assertion has no foundation, and experience has shown the imperfect working of these blow-pipes.

By a special adjustment of its blow-pipes the B. R. C. Company has realized the grouping in a head easily removable of all the parts, the form and section of which is variable with the required flow. The result is that with only one body of blow-pipe and a series of these removable heads, it is possible to obtain a great variety of flows, rendering possible the execution of very different classes of work.

This disposition is of value for the shops where oxyacetylene welding is seldom made, and on pieces of very different thicknesses.

3d. *General comparison between the blow-pipes of the first class (gas under pressure) and those of the second class (one gas driving in the other.)*

Certain shops, noticing marked differences between the work obtained with the same gases (acetylene and oxygen), but in one case with blow-pipes of the first class (gas under pressure), and in the other with blow-pipes in which one gas forces in the other, came to the conclusion that the former were superior to the latter.

This superiority, although real, is not, however, as great as one might be tempted to believe, because if certain blow-pipes where one gas brings the other in are not carefully watched, the few types generally used in the shops admit of a complete mixture of the gases and of a perfect mixture, the flame of which is in all respects similar to that of the other blow-pipes.

The inferiority, if it may be so called, of the blow-pipes of the second class, arises from the following fact:

When the workman starts to work and regulates the flame of his blow-pipe, its mouth is at the same temperature as the surrounding air. In the course of the work the diameter of this mouth increases in a certain proportion on account of the heat; on the other hand, particles of melted metal or oxide are always projected and may obstruct this mouth more or less. The result is that the volume of the issuing mixture is variable during the work.

In the blow-pipes where the gases come in under the same pressure this modification of the diameter of the mouth has no other consequence than a variation of the flow; the proportion of the gases in the mixture does not change, and it follows that the nature of the flame is not modified.

On the contrary, in the blow-pipes where one gas carries in the other, the quantity of oxygen passing under high pressure through the injector remains nearly constant, notwithstanding the variation of the orifice area, whereas the quantity of acetylene carried is subject to fluctuations. The consequence is a certain irregularity of the flame, generally hardly noticeable, requiring only a closer watch on the part of the workman.

CHAPTER III.

APPLICATIONS OF THE HIGH TEMPERATURES FURNISHED BY THE BLOW-PIPES.

The high temperatures that are so easily obtained by the use of blow-pipes have admitted of the execution of certain industrial works which were before impossible. We shall not speak here of the cutting up of metals, which will be the subject of a future article, but shall only indicate a few of the applications of oxyacetylene welding, limiting of necessity our description to the most typical current work. In fact, to enumerate all the cases where oxyacetylene welding has been the cause of any saving it would be necessary to review all the branches of metallurgic activity.

BLOW-PIPE WELDING OF STEEL PLATE.

One of the most important applications of oxyacetylene welding is its substitution for riveting and bolting in steel-plate work.

To assemble steel plates, and in general in all cases of assemblage by oxacetylene welding, "marking" is the first operation; it consists in making in various places along the pieces to be assembled several "drops" of welding, in order to maintain the two parts to be united in their respective positions. Then welding is done in the following way:

AB, AB′ are the edges of the two plates to be united, previously marked (Fig. 10).

We suppose that we start welding at *a*, moving forward toward *BB′*. The flame of the blow-pipe is allowed to act at the point *a* until it causes a fusion of the metal throughout the plate at *a;* the metal in fusion affects the shape of a drop. The flame is then brought forward from *a* to *b;* at *b* the same operation is repeated, and so forth.

In fact, the successive fusion drops *a, b, c,* etc., partially cover each other, and after cooling form an homogeneous mass.

The exterior face of the welding alone shows the way in which the work was done by a series of ridges outlining the

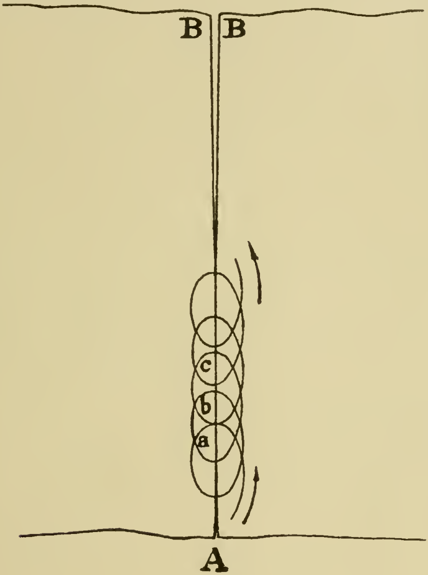


FIG. 10.

successive fusion drops. These ridges are more or less apparent, according to the ability of the workman and to the volume of the fusing drops, the latter being in proportion to the thickness of the plate.

In the assembling of two plates by oxyacetylene welding the quantity of lost metal (by oxidation, for instance,) being exceedingly small, the thickness along the welding line is practically the same as the adjoining parts, if there is no material space between the two parts to be welded. If, on the other hand, there is a space between them, it is necessary, after the edges of both plates have been brought to the melting point, to melt a rod of the metal, which the workman holds in his hand; this supplementary metal falls by drops on the melted edges and increases the melted mass in the proportion desired. The nature of this supplementary metal varies with the result to be obtained. Very often, in order to have an invisible welding line and not to modify the qualities of the metal along the latter, this line is "charged" by means of metal taken from the piece itself, such as strips taken from the plates; more frequently, in the case of iron or soft steel, the "charge" is made by means of ordinary soft steel wire, 1/8 to 1/4 inch diameter, according to the thickness of the piece to be soldered. The quantity of metal so added varies with the space between both parts before welding, and with the excess of thickness to be given to the welded part over the adjoining metal; naturally, this excess of thickness may be as great as the particular conditions may require, but in general it is very small, and a little chipping or filing is enough to take away the unevenness and bring the welded part to the level of the adjoining surface.

Thin plates (less than 1/16 inch thickness) to be welded with the blow-pipe require no special preparation of the edges before assembling. The above sketches show the various cases to be considered:

Fig. 11. Angle of the plates less than 90 degrees (concave bottom welded in a shell).

Fig. 12. Angle of the plates about 90 degrees. The assembling may be made, as desired, according to sketch *A* or *B*. Assembling *A* requiring no addition of metal is more rapid.

Fig. 13. Angle of the plates larger than 90 degrees (convex bottom welded in a shell).

Fig. 14. Angle of the plates = 180 degrees.

The welding of plates of more than 1/4 inch thickness requires a special chamfering of the edges. These sketches show various examples. In general the preparation must be such as to allow the flame of the blow-pipe to penetrate to the very bottom of the part to be welded; thus, there is no doubt that the entire thickness is affected. If in some cases it is impossible to make such a preparation it is then necessary to proceed slowly, in order to thoroughly fuse the entire section

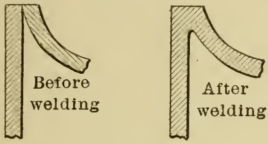


Fig. 11

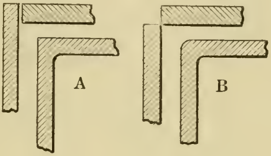


Fig. 12

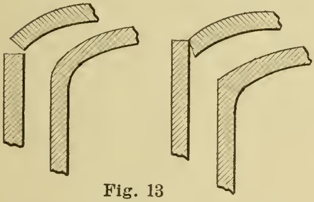


Fig. 13

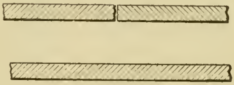


Fig. 14

of the metal. In this case it will be better if the plates to be assembled are not in contact but are 1/16 inch apart.

Fig. 15. Angle of the plates less than 90 degrees. Preparation *A* is better than *B*.

Fig. 16. Angle of the plates 90 degrees. Preparations *A* and *C* are better than *B*.

Fig. 17. Angle of the plates larger than 90 degrees.

Fig. 18. Angle of the plates = 180 degrees.

The most delicate welding is that of pieces with re-entering angles. This is, however, seldom the case; but if such is the case it is better, if possible, to prepare the piece according to sketch 20 or 21, or, if any advantage results from it, according to sketch 22 or 23, a rigid rib being obtained which prevents deformations of the piece.

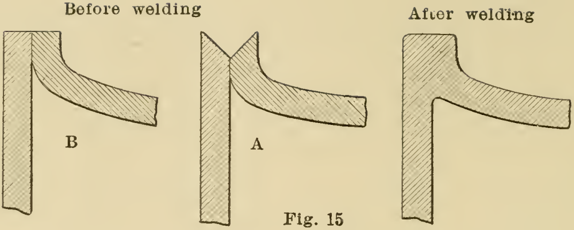


Fig. 15

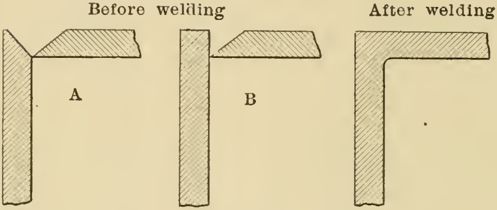


Fig. 16

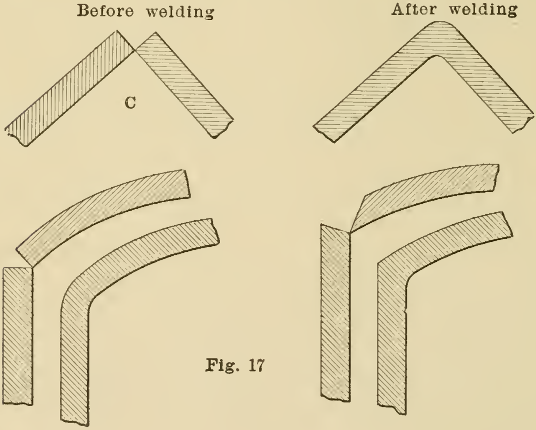


Fig. 17

In general, in preparing plates to be assembled by oxacetylene welding care should be taken not to imitate shapes previously requiring bolting or riveting.

In the majority of cases oxacetylene welding does away with a lot of preparatory work; calking of edges, pulling apart of rivets and other fastenings, operations always expensive and which are always to be avoided if possible.

Let us consider, for instance, the case of a cylindrical tank

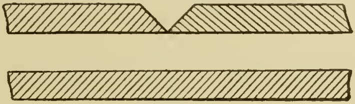


Fig. 18

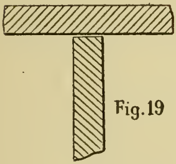


Fig. 19

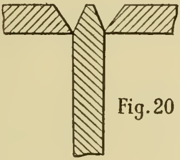


Fig. 20

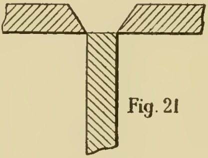


Fig. 21

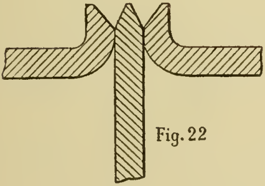


Fig. 22

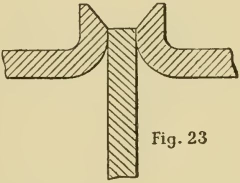


Fig. 23

with riveted bottom and head. If this tank is not of a sufficient diameter, and is not provided with a manhole, it will be necessary to make it with at least a convex bottom or head. Anyway, its making requires a riveted cylindrical shell with two drawn heads at the ends to permit the riveting of bottom and head and riveted bottom and head with calked edges.

The same tank can be made by oxyacetylene process with solid welded heads.

We may remark, in passing, that oxacetylene welding has rendered possible the making (volume and resistance being equal) of tanks less cumbersome and lighter than those used before its advent, in that it has made possible the building of tanks with two convex bottoms without regard to the diameter

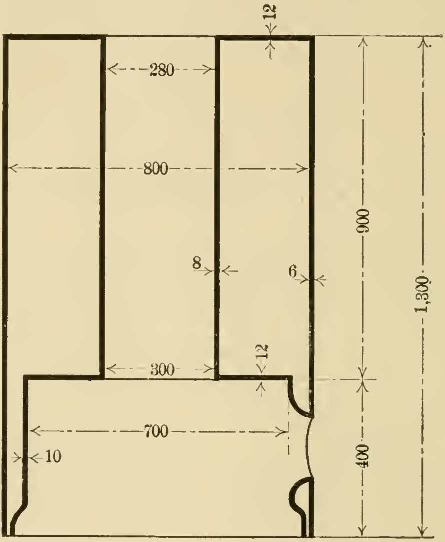


FIG. 24.

and absolutely free of the double thickness of plates necessitated by riveted coverings.

Nearly all the tanks built to contain gases under pressure or very thin liquids, such as petroleum, are now welded by the oxyacetylene process, because aside from the advantages of weight, bulk and price which they have over the riveted tanks, they do not leak, a quality which is difficult to obtain by riveting, and even with subsequent tin soldering, particularly when these tanks are supposed to travel and are, consequently, subject to continual rough handling.

Aside from the saving which may be realized by oxyacetylene welding over riveting by doing away, in a large measure, with preparatory forge work, we must also consider the economy of this process of assembling in itself.

Let us, for instance, consider the case of the ordinary riveting together of two plates of ¼ inch.

1st. *Riveting (One Line of Rivets).*

Diameter of rivets, ½ inch; number of rivets per foot = 8.

Price paid to the workman per foot of joint:

Laying out the holes	$ .006
Marking	.0066
Drilling	.0294
Chamfering	.003
Riveting	.0192
Calking plates	.0048
Calking rivets	.012
Total	$0.0810

This cost of workmanship, obtained in a part of the country where the salaries are not very high, does not include the general expenses arising from the necessary power, keeping, etc., of the machinery (punching tool, etc.) and heating of the rivets.

It follows that riveting in one line of rivets costs per foot:

Eight ½-inch rivets, 1.23 × 4 cents	$ .04
Workmanship (without general expenses)	0.08
Total	$0.12

Oxyacetylene Soldering (Generator Acetylene).

Chamfering of edges, per foot			0.0108
Welding	oacetylene	$0.0186	0.066
	oxygen	.0312	
	workmanship	.0162	
Total			$0.0768

This example shows conclusively that assemblage by oxy-acetylene welding is more economical than by riveting. To complete our comparison we shall consider the cases of the building of a vertical tubular boiler—shown in sketch No. 24—by oxyacetylene welding and by riveting. We shall not mention the operations, which are similar in both processes of manufacture: shearing and laying out of the plates, boring holes, assembling and expanding of tubes, etc.:

1st. *Oxyacetylene Welding (Generator).*

Chamfering of edges......	Shell,	8.5 ft. ×	$.0054	$ .046
	Furnace,	2.925 ft. ×	.0072	.021
	Uptake,	5.85 ft. ×	.066	.038
Welding................	Shell,	4.225 ft. ×	.066	$ .278
	Furnace,	1.462 ft. ×	.21	.307
	Uptake,	2.925 ft. ×	.12	.351

Rounding and planing after welding......................	$ .60
Forging of furnace (uptake and mouth)...................	2.40
Turning of circular plates..............................	.40
Assembling of the boiler (mounter and help).............	.80
Welding 32.5 ft. @ $0.27................................	8.78
Total..................................	$14.02

2d. *Riveting.*

Necessary plate:

For shell..............................	5.28 pounds	
For furnace............................	4.62 pounds	
For furnaces flanges...................	9.90 pounds	
For flanges of the outer circumferential plates, 51.48, total 71.28 pounds, @ $0.25		$ 1.78
44 ½-inch rivets, 5 pounds; 275 ¾-inch rivets, 112 pounds, 117 pounds @ $.04		4.68
Marking rivet holes....................		1.40
Flanging the uptake with forge heat....		1.00
Closing in on furnace boiler head flanges		.80
Forging the furnace (uptake and mouth).		4.00
Closing in the flanges of the plate	Inf., 105 pounds × $0.01	1.05
	Sup., 132 pounds × 0.009	1.19

Turning of circular plates		.60
Assembling the boiler		1.60
Riveting	5.5 ft. × \$0.08	.44
	35.75 ft. × 0.117	4.18
Chipping and calking heads		1.60
Total		\$23.32

The above prices of riveting are established on the supposition that the chamfering and calking are executed by compressed air (except for the heads, which require some hand work). They do not include the general expenses (material, coal and coke necessary for welding the charger and for the various forge work).

These results show the considerable saving obtained by judiciously using oxyacetylene welding in boiler making, and explain the development of this process as soon as it was known.*

The cost price may also be made much smaller by a preliminary warming up of the parts to be welded by means of the "Hauck" burner, using a less expensive combustible than the oxyacetylenic or oxhydric mixture. It is evident that in every instance where the method of manufacture, the shape of the pieces, the place where the work is to be done, will admit of such a warming up, a great advantage will result by such bringing of the parts to be welded to the highest practicable degree of heat; the more expensive combustible from the blow-pipe is thus used only to cause the actual welding, which the cheaper modes of heating cannot effect.

TENSILE STRENGTH AND ELASTICITY OF PIECES WELDED BY THE OXYACETYLENE PROCESS.

The experiments conducted on plates welded with oxyacetylene, or oxyhydric blow-pipes, show that the results are about the same if the proportions required to obtain a neutral flame

*These prices being those usual in French establishments must be proportion ately increased for American plants.

have been well kept. The unfavorable results that may have been obtained with either one of the methods were due solely to a defective regulating of the flame.

The tensile strength of pieces welded by the oxyacetylene process is practically the same as that of the metal itself, and in general is rather superior.

On the other hand, the elasticity is to some extent reduced, which seems natural, the welded part having been melted and then rapidly cooled, whereas the adjoining parts have been obtained by fusion, followed by slow cooling or by laminating or hammering, which operations increase the malleability.

If after welding care is taken to anneal the piece, the elasticity is restored and becomes equal to that of the metal in the primitive state.

In cases where the welded pieces have a tendency to stretch, it will be well, whenever possible, to anneal them after welding; it will be necessary to take this precaution in such works as boilers, superheaters, etc.

REPAIRS TO STEEL BOILERS.

In repairing in general, and particularly in repairing plates, the use of the blow-pipe is indispensable, because it very often happens that by its use pieces may be saved which otherwise would have to be replaced; this fact alone results in considerable economy.

One of the interesting applications of the oxyacetylene process is the repairing of boilers. Nearly all the work of this class accomplished up to the present time has been done with dissolved acetylene, because portable tools are most convenient for this class of work, as they avoid unnecessary handling of heavy parts, and on the other hand the lower temperature of the oxyhydric mixture renders its application impossible in repairs where plates are above ½ inch thick.

For an example we will mention some of the very interesting work performed during the year 1906 by the use of dissolved acetylene by the Société l'Acétylène dessous du Sud-Est in the harbor of Marseilles.

1st. *Repairing Cracks Steamer "Eugene Pereire" of the French Line, March,* 1906.

The boiler furnaces of the mail steamer *Eugene Pereire* of the French Line had numerous horizontal cracks above the grate bars. There were about 100 of these, and in two of the furnaces they extended from end to end of the corrugations.

It had been attempted to stop the worst of these by plugging; but it would have been necessary to renew several furnaces, which would have detained the steamer for two months and caused great expense. All the cracks were wedged open with chisels and welded; all repaired parts were annealed with burners. In two spots where there were several adjoining cracks, a part of the furnace was cut out and replaced by a welded piece. No leak was observed at any of the 100 places so repaired at the hydrostatic or steam tests.

Only the sweating of a few drops, caused by trifling laminations, were discovered, and a little calking restored the watertightness at such spots. The work lasted three weeks and cost $300. From the month of March of that year the steamer has been on the Algiers voyage, which is very trying for boilers on account of its shortness, the fires being banked and boiler temperatures changed so frequently. No trouble has been experienced with any of the welded parts.

2d. *Assembling of Welded Pieces; Work on the "Marsa," June,* 1906.

The unreliability of riveted patches on damaged boilers is well known, particularly where the rivets are exposed to fire. The use of oxyacetylene welding, by which two pieces may be united end to end without butt straps, brings the plates to their original condition and avoids all the inconveniences of rivets. The work performed on the *Marsa* offers a remarkable example of the results that may be thus obtained.

Of the four furnaces of this steamer, the steel plates *A* and *B* riveted top and bottom to the fire-box, and the plates composing the back end of the combustion chamber, *C and D,* were completely worn out. Portions of these plates 18 inches to 36 inches long were cut out and replaced by welded pieces, as indicated in dotted lines on the sketch (Fig. 25.) This work was very successful, except on one of the sixteen pieces, which was later replaced by a riveted patch. The welded part of this

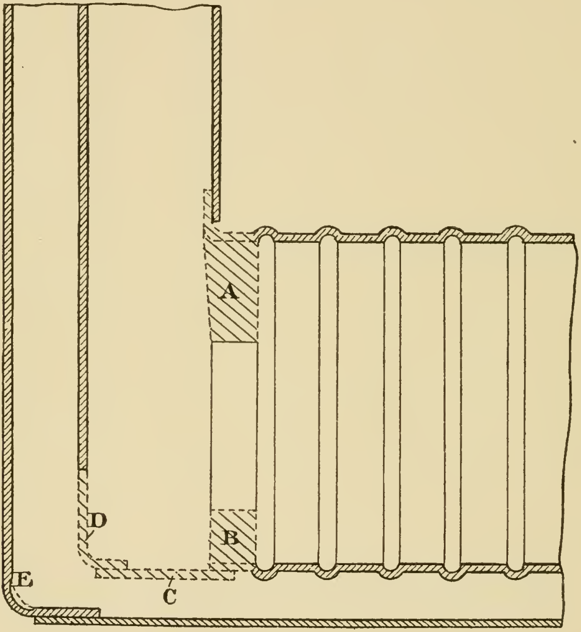


FIG. 25.

piece broke several times, but observations made in the case showed a defective quality in the plate to which the new piece was joined. The other fifteen held good. In the course of the work it was noted that the plates of the bottom of the boilers were badly eaten away at *E* on a space of about 36 inches; oxyacetylene welding was used to restore these plates to

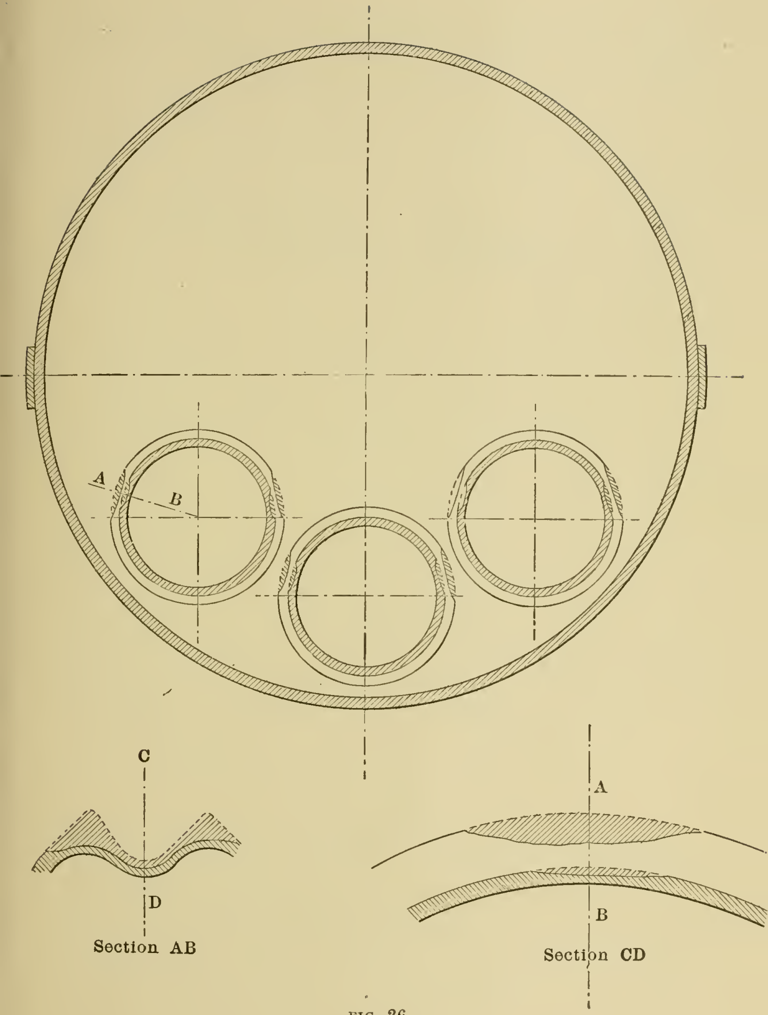


FIG. 26.

their original condition. In some spots they had been reduced by corrosion to a thickness varying between ⅛ and 1/16 inch.

3d. *Repairing Corroded Parts on the "Cholon."*

Oxyacetylene welding may be used to add metal directly to the surfaces of plates, to repair corroded spots, such as are frequently found in various parts of boilers. The flame of the blow-pipe is directed upon the plate, and when the latter begins to melt the workman presents to the flame a bar of soft steel about 7 by 7, which melts and fixes itself in drops on the corroded surface.

The repairs of the *Marsa,* already referred to, give a sample of the value of the welding process, but the work performed on the *Cholon*, of the Compagnie des Chargeurs Réunis, from Aug. 20 to Sept. 20, 1906, presents a still more striking case.

The eighteen corrugated furnaces of this steamer were badly eaten away on the surface. There was corrosion on each side and for some distance above the grate bars.

The work was difficult to perform, as the workmen were compelled to be inside of the boilers; and were inconvenienced by the heat of the blow-pipe flame; and the places to be welded were lower than the workmen's footing; 10,000 cubic feet of dissolved acetylene and as much of oxygen were used; about 200 pounds of steel were used to cover the corrosions and restore the plates to their original thickness. This work, at a total cost of $2,400, avoided the replacing of eighteen furnaces, as originally ordered by the government inspectors.

4th. *Repairing Boiler Heads Worn by Corrosion or by Repeated Calking.*

A frequent fault in marine boilers is due to the grooving of the flanged furnaces riveted to the combustion chamber. These heads are under great stress on account of the expansion. Leaks, which are in some cases frequent, require calking; but each calking reduces the width of the collar or flange, and after a series of calkings the parts are practically worn out.

By the use of oxyacetylene welding such defects can be very easily repaired. An addition of material restores the plates to their original condition. The work is at times a lengthy one, but presents no special difficulty. Advantage is taken of a preliminary heating up to reshape, if necessary, the

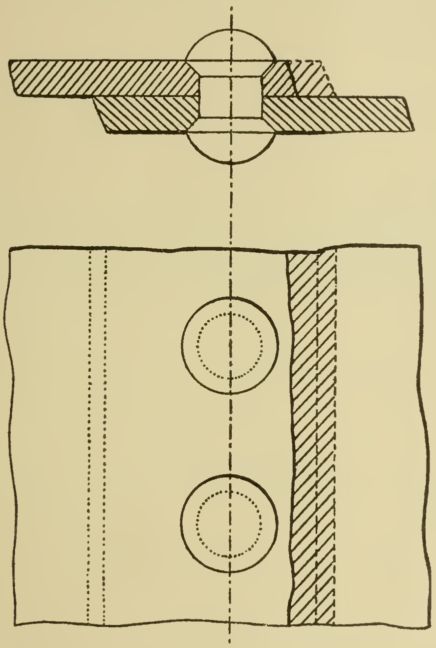


FIG. 27.

piece to be repaired, to insure its close contact with the plate to which it connects.

By making repairs as soon as a defect is noticed, boilers may be kept in perfect condition and last indefinitely; such repairs delaying the running schedule to an insignificant extent.

Railroad companies are by this process enabled to repair their locomotive boilers at trifling delay, and consequently to reduce considerably the capital otherwise tied up in repair shops.

MANUFACTURE OF THIN STEEL TUBES.

The methods employed up to the present time for the manufacture of seamless drawn metal tubes are not economical for very thin tubes, such as bicycle tubes or water or gas pipes of large diameter.

Oxyacetylene welding solves this problem. The plates are bent to form the circle, the edges being forced into close contact.

The edges are welded by a blow-pipe, the tube is then drawn through a form to rectify the thickness of the metal and give

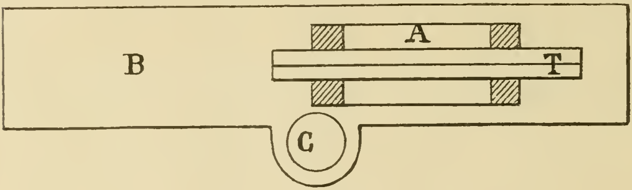


FIG. 28.

to the tube the finished form, which cannot be exactly obtained by bending.

Tube manufacture presents no peculiarity; but the large number of similar pieces which are made at the same time has brought about the adoption of a special welding process.

The rapidity of welding depends upon the power of the blow-pipe used, the thickness of the parts, the total bulk of the pieces, and on the nature of the metal. In the manufacture in quantities the factors do not vary; the result being that the rapidity of welding is practically constant. It is, however, evident that a workman, performing the work by ordinary process, cannot, however great his attention, maintain an absolutely steady pace; the ordinary welded metal along the joint is therefore irregular, and this spoils the outward appearance of the work.

It is natural that in these manufactures in great quantities, automatic movement of the blow-pipe over the joint must be sought. The problem has been solved as follows:

The tube *T*, Fig. 28, secured with its two edges to be united in proper contact, is placed on a carrier *A* moving on a bench *B*. This carrier is automatically run at the speed found necessary for the thickness of metal to be welded. On an extension *C* of the bench *B* is placed the blow-pipe.

The work is generally performed by a woman or a boy. The blow-pipe flame is regulated above the seam to be welded;

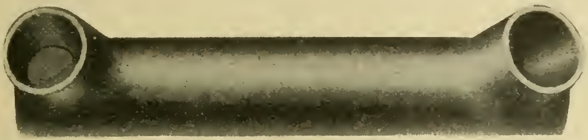


FIG. 29.

the carrier *A* is set in motion. The tube runs under the flame and is automatically welded.

The operator has only to watch and adjust the flame of the blow-pipe so that it strikes the seam.

This simple method does not require skilled operators to obtain sound welding, and if properly regulated the metal is united at all points along the seam.

Whenever the work so warrants this automatic running of the piece under the blow-pipe should be adhered to.

MANUFACTURE OF TUBING OF SPECIAL SHAPE.

We shall here mention several special articles of manufacture which are rendered economically possible only by the application of the oxyacetylene process: The manufacture of partitioned tubes, the partial partitions of which guide the fluids circulating inside; manufacture of handle bars, etc., for bicycles (Fig. 29); the forming of elbows impossible to obtain by bending, whether on account of the small radius of the bend or of the thinness compared with the diameter.

In the case of large diameters, and when the regularity of the shape is not absolutely essential, the elbow may be made of cylinders welded together at the desired angle.

IRON, STEEL AND BRASS TUBES.

As soon as blow-pipes were found satisfactory, pipe-manufacturing shops were provided with installations which rendered practicable, at small cost and with absolute guarantee, work that had previously been impossible of performance.

At the present time pipe manufacturers in France possess oxyacetylene welding apparatus by means of which they are able to make in short order changes or repairs to their plants which heretofore caused long delays and required taking apart and reassembling of machinery and the attention of special workmen.

End to End Welding.

When two tubes have to be united end to end, and they are not more than 3/16 inch thick, it is only necessary to cut the ends at right angles. If more than 3/16 inch thick the ends must be chamfered, and the welding is then made as mentioned in the case of plates.

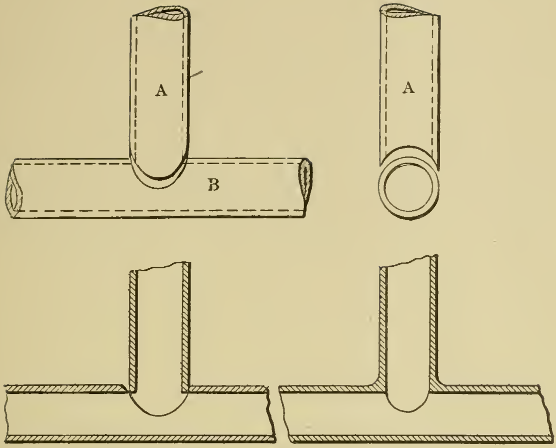
It is thus possible to obtain coils the developed lenghts of which attain miles without any flange or other joints, which completely avoids the leaks and the consequent hard and costly work of examining and replacing the gaskets.

Pipe Branches.

Oxyacetylene welding avoids the making of collars in branch work. It is only necessary to give to the end of tube *A* the curve of tube *B*, with which it is to be connected, and to fit it snugly into an aperture in the latter, and bring the parts under the flame.

Welding on Flanges.

Many accidents have occurred in consequence of the destruction of ordinary brazing, due to the voltaic couple formed by the contact of copper and zinc. It is a well-known fact that



Before welding After welding

Fig. 30

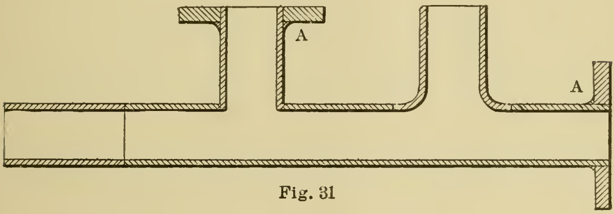


Fig. 31

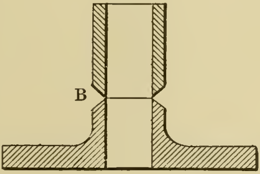


Fig. 32

a hammer stroke on an iron flange brazed on an iron pipe results, in many cases, in a failure of the brazing. Oxy-acetylene welding absolutely avoids this cause of possible accident, as there is no interposition of a chemically active metal.

The work may be performed as in Fig. 31, by using the ordinary flanges and making in *A* an addition of a proper amount of metal to fill the joint up solidly. If the diameter of the flange is large in comparison with its thickness, and trouble is feared through the heating of its center and buckling, it is preferable to provide the flange with a boss and to make the weld in *B* (Fig. 32).

Flange work costs somewhat more than brazing, unless care has been taken to bring the parts to red heat by some inexpensive fuel before the welding flame of hydrogen and acetylene is turned on.

But the safety is much greater if the pipes are to be kept at high temperature and pressure, such as with superheaters, digesters, etc.

REPAIRING OF CRACKS, FITTINGS, ETC., IN IRON AND FORGED STEEL PIECES AND IN CAST-STEEL PIECES.

By application of the oxyacetylene flame, cracks and pittings in any iron or steel pieces may be repaired rapidly and economically.

In the case of cracks and blisters a groove must first be made to enable the flame of the blow-pipe to reach the bottom of the defect. The flame of the blow-pipe is then turned on until the metal reaches a white welding heat. A piece of (preferably the same) metal is then presented to the blast until its melted drops solidly fill the crack.

Numerous steel manufacturing plants in France now use the blow-pipe to repair blisters in castings, and manufacturers in general find in it a most valuable instrument, which prevents the necessity of discarding pieces in which defects may be discovered, very often after large sums have been expended for workmanship. Portable apparatus is in this case particularly handy, as the piece may be repaired without taking it from the machine-tool (lathe, planer, etc.) on which it may be adjusted.

The steamer *Le Gaulois* broke her stern post, the section of the broken part being 4 inches by 9 inches. The edges of the break were first chamfered with a special acetylene burner in fifteen minutes, and the welding proper was then performed in eight hours by the use of dissolved acetylene; 1,225 cubic feet of this gas were consumed. To replace this stern post would have cost from $3,000 to $4,000, and detained the steamer a considerable time.