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of the

American Bureau of Welding

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THE movement towards the scientific advancement of welding conducted by the Emergency Fleet Corporation, and now, since necessarily dropped by the Government, in the hands of the **American Welding Society**, has reached a stage where its proceedings should be regularly published. It is for this purpose that this Journal has come into being.

The Emergency Fleet Corporation had for its Welding Committee a body of experts on the subject. It comprised representatives from this country and England, from the Army and Navy, from educational institutions, from the ship underwriters, ship builders and manufacturers. With the close of war, when the Government withdrew from the activities created by it, this organization like so many others was left with important work on its hands uncompleted. It represented a vast amount of time and thought, and considerable sums of money, and not to continue its work would have been wasteful in the extreme. It was necessary therefore to create a body of equal weight and authority to replace the former Committee. To accomplish this, the AMERICAN WELDING SOCIETY, organized mainly by members of that former committee, invited delegates from leading scientific societies and from departments of the Government acting not merely as individuals but as representatives of their respective organizations to come together with its own representatives and form a permanent organization. This body became the AMERICAN BUREAU OF WELDING and its function, like that of its predecessor, is to establish and standardize the facts, conduct such researches as may be needed and thus furnish a sound basis for the development of an industry bound to be of the first magnitude.

As welding enters into all the fields where iron and steel are used, an advance in it would mean an enormous increase in the productivity of the country. Welding has not developed as it should, for lack of such an authentic source of information.

The AMERICAN BUREAU OF WELDING is the authoritative body to establish the facts. To make the most use of the facts, however, requires another sort of machinery and the organization that does this is the AMERICAN WELDING SOCIETY. Its function is not to supply the knowledge but to spread it and assist in putting it to practical uses. It is the Society, for instance, which publishes this Journal, which will push matters of importance to welding and which will open out new fields for its use. It holds regular meetings to discuss matters relating to welding, to act upon the recommendation of the Bureau and to initiate further activities.

This division of the work, while it has created some confusion on account of the similarity of the names, is a logical one, and will be found effective in operating as was clearly indicated by the experience with the old Welding Committee.

* * * *

IT is an obligation of the community to open everything possible to the **Men Disabled by the War.** Therefore the AMERICAN WELDING SOCIETY takes this opportunity of explaining what welding has to offer. On the whole it has more than other trades, as disabilities are of less moment and are more easily made up for by artificial means. Furthermore, in welding, however much processes may be improved, in the last analysis the sole dependence probably always will be placed upon the welder himself. He is the one who really knows what goes into the weld. So the moral quality of the welder, his conscientiousness and reliability, more than make up for physical deficiencies.

For a man who is a skilled welder, two further fields are open — the first is that of inspector. In this work restrictions would count for comparatively little. Care and thoroughness would again be the chief requirement. The second is that of the independent jobber. Since welding has been developing there is distinctly a place for the man with an all round experience who can go from place to place with his own equipment and work for companies that have not the facilities for doing their own welding. The equipment needed to conduct this business is a small auto-truck, carrying a complete welding outfit. Inasmuch as most of the materials needed for this are owned by the Government and are being disposed at a sacrifice, it should not be difficult to work out a plan with the Government to set up disabled men in this business upon easy terms of payments.

The AMERICAN WELDING SOCIETY presents in this issue a plan for training, but as it would be some time before any of these men would desire a jobbing outfit, it would seem better to meet this problem when it arises.

COMFORT AVERY ADAMS *President* AMERICAN WELDING SOCIETY

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Our Perspective

By COMFORT A. ADAMS

THE whole civilized world is in a state of fermentation. What is the cause? Some tell us that it is the war, but is this not a superficial explanation? Was not the war merely a stimulus or aid to the fermentation already started? The fact is that the work of the engineer has brought the ends of the earth closely together—has made the nations of the earth inter-dependent. This has made large combinations or organizations of all kinds not only possible but necessary. As yet the human race has not learned how to control the power of these enormous organizations, whether of nations, of capital, or of labor. We have not learned yet how to make them serve society and thus make the world a better place to live in.

The great war is over but the spirit of war still prevails. The only difference is in the size of the units involved — whether they be nations against each other, organizations of capital against each other, organizations of capital against organizations of labor, or even a struggle between organizations of labor, each trying to raise its own head above that of the others.

But how futile all this is, for it is nothing more than a struggle on the part of each group to get a larger share of the wealth produced by them all, a struggle to get up by climbing on the other fellow's back, to get something by taking it away from the other fellow. This kind of war is just as wasteful of time and energy as is the ordinary variety, and, moreover, it is going on all the time, whereas the ordinary variety has intervals of cessation. It can only result in a reduction in the total product of labor and therefore in the average reward of labor.

Moreover this kind of war almost invariably develops a habit of dishonesty and distrust, or at least of stretching the truth, which is one of the most vicious influences in our business life. I do not refer to clean, wholesome competition.

It is the simplest possible axiom, when we stop to think—and few people ever do stop to think—that the only way, in the long run, for labor as a whole to get more wealth, is for it to create more wealth, and the only way to create more wealth is to increase the productivity of labor, or, to use a much abused word, to increase the efficiency of labor, which means co-operation on the one hand and the introduction of labor saving methods on the other.

Just here is where the American Welding Society comes in, for one of its chief functions is to increase the application of welding, which is one of the greatest labor saving processes of the past few decades. Its predecessor, the Welding Committee of the Emergency Fleet Corporation, was animated in no inconsiderable degree with the spirit of co-operation, and it is the hope of the promoters of the Society that this spirit will be carried over.

The field for further application of welding is enormous, but this further application is being delayed by lack of complete knowledge of the art of welding, and by the utterly confusing and, in many cases, diametrically opposing claims of competing interests. These hindrances ought to be removed and they can be removed by the successful conduct of research work, and by a cultivation of the co-operative spirit which will permit a frank, open discussion of the merits of the different processes, and a reasonable agreement as to those merits.

If you were a prospective user of welding and were in doubt as to whether to use gas or electric welding or neither, do you think that your confidence in either process would be enhanced by having its exponents claim that it was the only safe and economical one? How much more confidence you would undoubtedly have, if you were told by the exponent of each, that in such and such fields the other was preferable.

I am not setting forth impractical ideals, but rather the most common sense principles already found successful in many business fields, the application of which is bound to yield the best results for all concerned.

Here then is our job, let us go to it with confidence, energy and enthusiasm, and let us remember that its successful completion will not only mean much to the welding industry, but that it will increase the average productivity of labor, and thus in some degree help to solve the greatest problem of this very critical period in the world's history.

A Theory of Metallic Arc Welding

By RALPH G. HUDSON

There are conflicting theories as to how the electric current acts in arc welding, and how it should be controlled. Such a controversy will exist until there is a thorough understanding of the fundamental principles of arc welding. Prof. Hudson's investigations on this subject show that the function of the electric current is apparently nothing more than to furnish heat in the form of the electric arc. The welding is accomplished by metal that is expelled from the electrode in the form of metallic vapor, and minute liquid particles which are shot across to the plate opposite at the rate of some fifty a second. The force that propels these particles is the pressure that arises from the sudden formaton of vapors and gases under the intense heat of the arc. Carbon monoxide is the gas mentioned, and the vapors are those of the lower melting constituents of the electrode. The particles that strike fluid metal on the plate solidify with it; but those that strike solid metal either bounce off and are wasted, or adhere without fusion and are a cause of bad welding. One great advantage of maintaining a short arc lies in the fact that it secures a better concentration of the projected particles within the fluid spot on the plate.

IN the summer of 1918 the Welding Committee of the Emergency Fleet Corporation initiated an investigation of metallic arc welding in which special attention was to be given to the determination of the cause and nature of the transmission of metal from an electrode to a plate. Although metallic arc welding had been employed successfully for a considerable period it was appreciated that its application was based upon empirical methods, and to make greater use of such welding in shipbuilding it was evident that its basic principle should be investigated as thoroughly as possible so that inferior methods of metallic arc welding might be eliminated. The object of this paper is to present the results of an investigation of this character conducted in the laboratories of the Massachusetts Institute of Technology.

It should be noted that at the beginning of this investigation no satisfactory explanation had been given for the transmission of metal from electrode to plate. In downward welding the deposition of metal might be attributed to gravitational force but in upward welding no such explanation could be offered. The fact that an electric current is employed in the process suggested the possible existence of forces of electrical origin which might pull metal from the electrode to the plate. Calculations of the magnitude of the electrical forces that may exist during metallic arc welding indicate that they are negligible and may therefore be eliminated as possible causes of the action. This view is further substantiated by the fact that satisfactory welding may be performed with current flowing in either direction or with alternating current and that such differences as may exist with different directions of the current may be explained by consideration of the relative heating properties of such currents at the terminals of an electric arc.

In conducting this investigation the writer, following the suggestion of the Committee, first attempted to obtain a photographic record of successive phases of the welding arc by means of a high-speed motion picture camera. The camera was specially constructed and when set up was found to operate satisfactorily at a rate of thirty-two pictures per second; the ordinary camera operates at sixteen pictures per second. One thousand feet of film were exposed with this camera, the character of the arc being varied by changing the direction of the current, length of arc, type of electrodes, etc. In photographing an electric arc of any kind the luminosity of the arc itself is so great that the other parts of the apparatus — electrode, plate, molten drops, etc., — do not appear on the film except as they may appear in silhouette against the arc. The films thus exposed therefore show only various shapes of the arc itself and an occasional view in silhouette of the electrode and plate. Since motion picture negatives are necessarily small in area, a full size reproduction here would be of little interest and it was found that magnification of the film pictures only disclosed their silver grain structure without adding to the detail.

The principal use made of these films by the writer was to examine them one by one with a low-power microscope with transmitted light. A systematic examination of sixteen thousand pictures in this manner disclosed certain important features mentioned later. Although the photographic difficulties were evident, the writer decided to take further magnified pictures of the arc with a short exposure focal plane shutter. A camera was set up which would magnify the arc about eight diameters. Instantaneous photographs of the welding arc obtained with this camera suffered from the same domination of the plate by the arc to the exclusion of all other phenomena.

While focusing this camera it was realized, however, that more could be seen with the eye on the ground glass than could be obtained photographically or by direct observation through dense glasses, and the writer therefore began an extended study of metallic arc phenomena as seen in magnified form on the ground glass.

With this device the action of the arc could be examined without screening the eyes and with the further advantages offered by magnification and observation of the action in its true color.

When an arc is struck between a steel electrode and a steel plate the end of the electrode and a spot on the plate are heated to a high temperature and metal is transferred from the electrode to the plate. The electrode is heated to a higher temperature than the plate because the heating action of the arc is more concentrated in the case of the electrode and because the heat conduction away from the hot spot is greater in the case of the plate. An analysis of steel electrodes usually reveals the presence of at least ten elements: iron, carbon, manganese, copper, sulphur, phosphorus, silicon, oxygen, nitrogen, and hydrogen. Since the melting points and other thermal constants of these elements and their compounds vary widely and their chemical affinities are quite different, it is to be expected that the constituents of an electrode subjected to a high temperature will change from solid to liquid or gaseous form successively and not at the same instant. Since the melting point of iron is higher than that of any other constituent of an electrode with the exception of carbon, which combines rapidly with oxygen at welding temperatures to form carbon monoxide, it is furthermore to be expected that in the welding process the iron constituent of the electrode will melt last.

The thermal changes just described are known to take place during the application of heat to any complex substance. In metallic arc welding the temperature changes which take place differ, however, to a marked degree from the changes incident to the usual methods of heating metals in that a small mass of the electrode in welding is subjected to a high temperature for a very short interval of time. The distinctive thermal feature of metallic arc welding is then the sudden rise and fall of temperature in the metal transmitted to the plate. Under the circumstances it may be seen that the melting of the iron is delayed by the heat absorbed by the other constituents of the electrode and that this fact together with the limited time of application of high temperature disproves the possibility that the iron is completely vaporized in the welding process. When a projectile is fired from a large gun, for example, the initial temperature of the gas behind the projectile is believed to range between 3000 and 4000 degrees Centigrade. Although this temperature greatly exceeds the melting point of the material of the projectile, there is little evidence of melting on the surface of the projectile because the projectile is not heated by the adjacent gas for a period long enough to melt its surface.

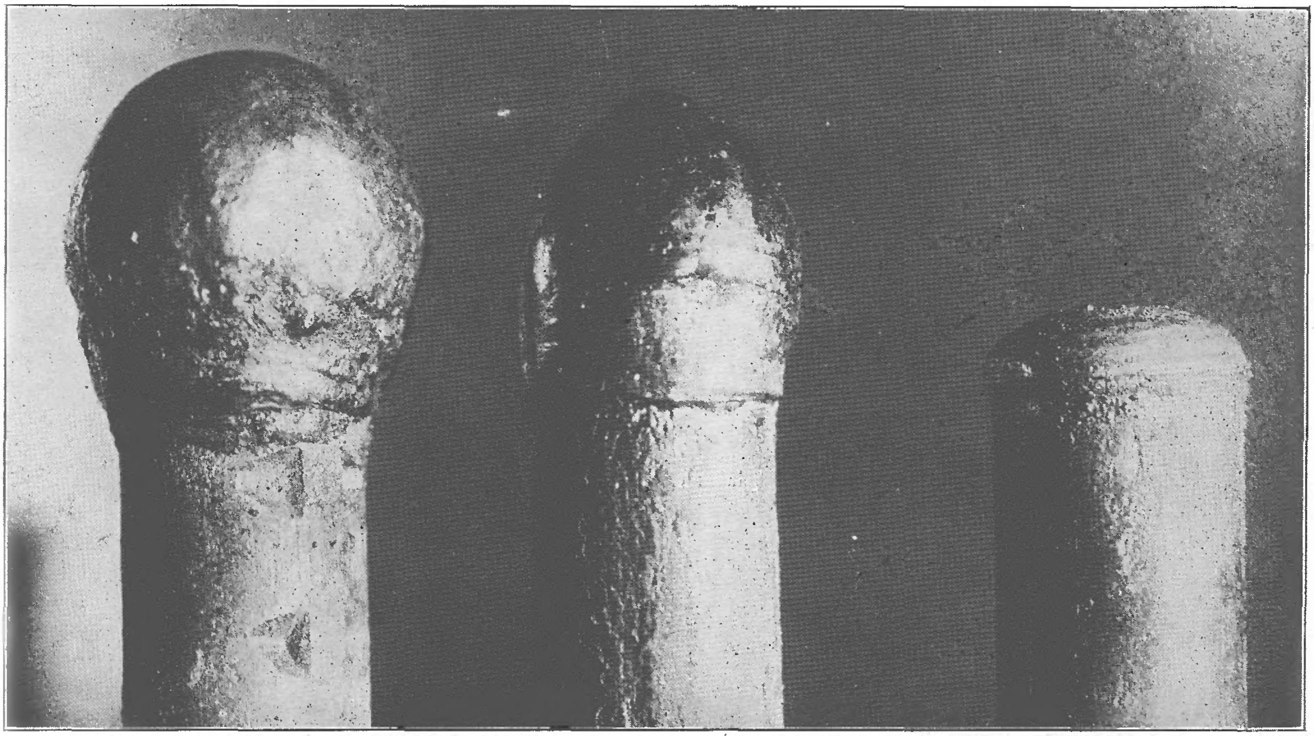

FIGURE 1.—Effect of length of arc upon the size of the electrode globule. At the right, a globule developed with a very short arc; in the middle, with a moderate length of arc; at the left, with a very long arc. These are $\frac{3}{16}''$ electrodes magnified 6.8 diameters. The current strength in each case was 100 amperes. Each globule contains a cavity; in the smaller globules, the cavities are usually open, and resemble small drill holes, while in the larger ones they are usually closed and are surrounded by a thin skin of metal.

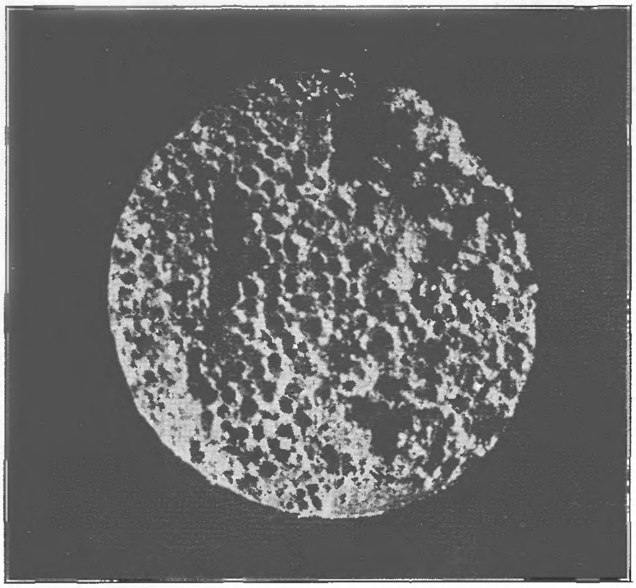

FIGURE 2.—The surface of an electrode on the interior electrode end of a large globule. The pitted surface suggests irregular fusion of the electrode due to different temperatures of fusion, vaporization and chemical combination of the ingredients under the influence of rapid changes in temperature. Particles may be seen under magnification to emerge from these cavities during welding. The magnification is 9.6 diameters.

An increase of temperature in most materials is accompanied by a marked increase in volume and in chemical changes resulting in the formation of gases the reaction is usually accompanied by an immense change in volume. While various changes in volume may take place among the constituents of the electrode during metallic arc welding, the greatest possibility for such expansion may be found in the formation of carbon monoxide. It is therefore to be expected that a globule will be formed by such expansion on the end of the electrode during welding. Typical electrode globules developed in this manner by various lengths of arc during the welding process are shown in Figure 1. Each globule contains a cavity which may be seen clearly during welding on the ground glass of the camera described above and is also present in the cold contracted globules shown in the figure. In the smaller globules the cavities are usually open and resemble small drill holes, while in the larger globules the cavities are usually closed and are surrounded by a thin skin of metal.

An electrode globule maintained in continuous contact with the plate to prevent the formation of the glaring arc and heated by a heavy current may be seen under magnification on the ground glass to expand and blow out minute particles at high velocity from the thinnest side walls, a contraction of the globule occurring after each expulsion of particles. The particles appear to originate in the inner electrode surface of the globule. If the globule is suddenly detached and the arc interrupted at the same instant in ordinary long arc welding, the inner electrode surface of the globule presents the appearance shown in Figure 2. The pitted electrode surface suggests irregular fusion due to different temperatures of fusion, vaporization and chemical combination of the ingredients under the influence of rapid changes in temperature.

Owing to the complex structure of the electrode, it is not easy to determine the exact nature of the vapor content of the globule. That the vapor consists partly at least of carbon monoxide gas is suggested by the fact that such globules do not form in general when the end of the electrode is heated in a reducing (deoxidizing) atmosphere. It is also found impossible to weld with an electrode containing practically no carbon in a reducing atmosphere. In welding under water it was observed that bubbles of gas rise continuously to the surface of the water and burn, indicating the possible dissociation of the water with the absorption of oxygen by the electrode and the rejection of hydrogen to the surface of the water. After a globule had been maintained for several minutes at high temperature in contact with a plate in air, it was observed that all expulsion of particles ceased. It may be inferred from this that all of the vapor forming constituents of the globule had been burnt out.

An examination of the motion picture films which show successive views of the arc, each with 0.0005 sec-

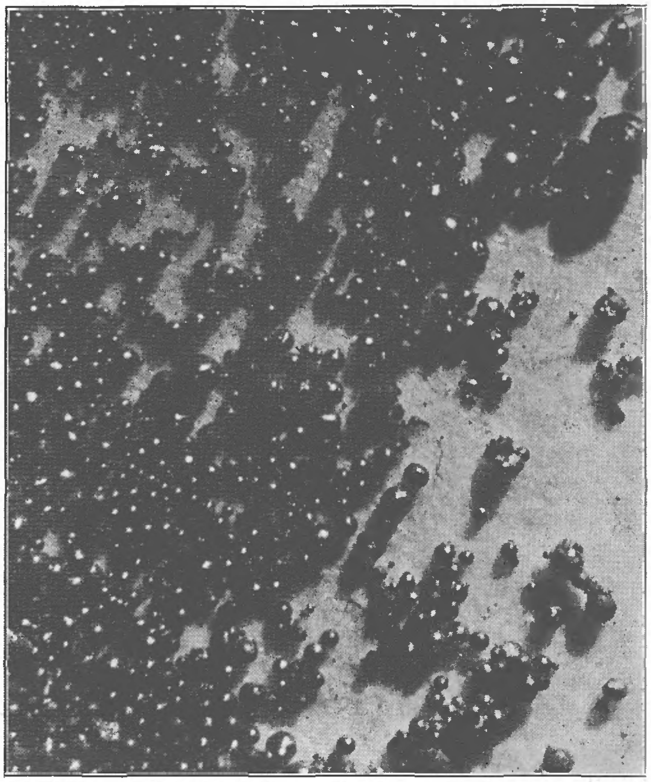

FIGURE 3.—A photograph of the dust which accumulates around the work during metallic arc welding. The magnification is 20.7 diameters. This dust consists of projected particles which solidify without fusion with the plate and in many cases become connected to other particles forming chains. It will be observed that in general the projected particles are almost perfect spheres. They may be crushed easily as the interior is usually hollow.

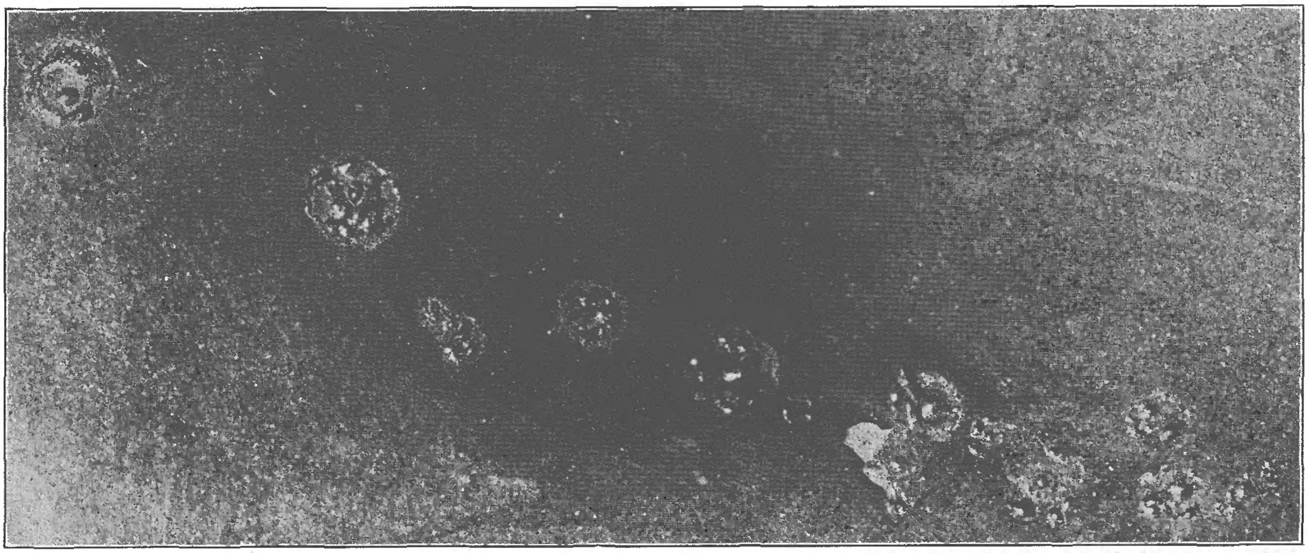

FIGURE 4.—Metal projected from a hot electrode globule to a cold electrically insulated plate when an incandescent electrode is moved at a speed of four feet per second over the surface of the plate. The photograph shows only a small portion of the projected metal, the remainder being scattered beyond the region photographed, or having become detached from the plate together with some of the flaky oxidized surface. The magnification is 8.2 diameters.

ond exposure, reveal occasional protuberances on the electrode globule within the crater region and the paths of projected particles may also be seen silhouetted against the arc itself. That these phenomena are only found at intervals in examining the film is undoubtedly due to the fact that such particles in the arc stream are rendered invisible by the luminosity of the arc and that such protuberances and projectile paths are only visible when they happen to screen the arc. The expelled particles found about the work when welding—the familiar bluish-grey dust of the welding room—or when collected under water are found to be spherical shells indicating that a portion of the vapor within the globule is carried away with the projected particles. A photograph of these projected particles, magnified 20.7 diameters, is shown in Figure 3.

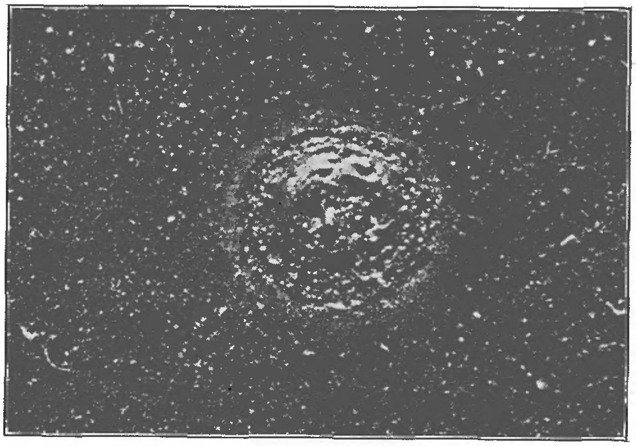

FIGURE 5.—A higher magnification, 16.7 diameters, of a nucleus of metal projected on a cold plate from an incandescent electrode globule. Metal is thus projected by heat effect alone at regular intervals with an average frequency of 50 projections per second. The actual diameter of such projected spots ranges from 0.01 to 0.05 inch.

If the electrode while welding is suddenly swept across an adjacent flat insulated surface, small spots of metal are found on the surface at regular intervals over the surface traversed by the hot electrode. A photograph of a small portion of such a path is shown in Figure 4 and a more highly magnified view of one of the spots in Figure 5. The regularity of spacing of these spots when the differences are not magnified is quite striking. The same effect was observed by holding an incandescent electrode—just removed from ordinary welding—over the rim of a revolving iron wheel. It was determined in this way that the average frequency of projection was 50 per second. The duration of such projection was approximatelv one-fifth of a second; the projection terminating with the cooling of the electrode.

It would appear from the observed facts that the metal deposited during metallic arc welding is transmitted in part at least in the form of minute particles which are projected from the electrode globule by the internal expansion of some vapor, possibly carbon monoxide. The expelled particles pass through the arc too rapidly to become vaporized and reach the plate in a fluid state. If the expelled particles strike solid metal they either ricochet along the surface—which explains the accumulation of iron dust in the welding room—or flatten out without fusion, the most common cause of poor welds. If the particles strike a fluid metal they penetrate the fluid and solidify with the molten surface of the plate.

It is a well-established fact that the best welding is obtained with the shortest arc and the worst welding with the longest arc. It will be noted in Figure 1 that the size of the electrode globule also increases with the length of arc, the best welding being obtained with the smallest globule. A small globule implies greater concentration of projected particles in the direction of the opposite fluid spot. In downward welding a large globule becomes elongated by gravity, the lower part of the hollow globule becomes thickened by downward flowing metal, the side walls become stretched and thinned, and particles are projected wastefully through the side walls at right angles to the arc. The globule as a whole frequently breaks away from the electrode and drops without fusion on the plate. Electrode ends rejected by a welder and presenting the appearance shown in Figure 2, or the large globule in Figure 1, constitute substantial evidence of ineffective long-arc welding. In upward welding a large globule tends to fall to one side or the other by gravity and prevents the efficient projection of metal.

Any material which serves to increase the melting point of the surface of an electrode must, in accordance with the stated theory, improve the conditions under which particles are projected from the electrode globule. The cup shaped surface formed at the end of such an electrode will reduce the amount of indirect projection of particles to a minimum and the increased stability of the arc will reduce the difficulty of manipulation of the electrode, since the length of arc may be varied over a greater range without interruption. It would appear that most of the coatings suggested for electrodes perform the function of cooling the surface of the electrode by vaporization and in some instances, owing to the rapidity of the action, remain in a fluid condition about the sides of the electrode globule. It should also be noted that since iron oxide (rust) has a higher melting point than steel, that rust should not be removed from electrodes and that rusty electrodes will usually work better than bright clean ones. In many cases the outside layer of bare electrodes may be changed by drawing and heat treatment so that it has a higher melting point than the interior. The ideal electrode would have a high melting point shell—tungsten for example — surrounding a lower melting point interior containing sufficient vapor forming constituents to eject metal constantly when heated by the electric arc.

The writer would suggest certain promising subjects for further study. First, a determination of the character of the vapor found in an electrode globule. Second, a determination of the best surface material for electrodes; first cost and effect on the finished weld to be considered. Third, the effect of welding in a reducing flame upon the character of the weld. The writer has found that such a weld is more ductile and reveals less formation of nitride. Fourth, an investigation of the value of welding under water as in the case of ships, tanks, etc. Fifth, the use of materials other than steel in metallic arc welding. It will be noted, for example, that the zinc constituent of brass under the influence of a rapid increase in temperature may melt and vaporize before the copper constituent begins to melt. If the theory outlined above is correct, it would appear quite probable that satisfactory welding could be done with brass electrodes.

Plan for Men Disabled by the War

The directors of the American Welding Society, at their meeting on September 26, 1919, passed the following resolution:

> "That the American Welding Society recognizes the obligation of the community to the men disabled by the war, and, in the field of welding, will endeavor to translate this recognition into a specific program of assistance; that its earnest desire is to work out a plan that will be practical, and from which these men may benefit."

Conforming to this resolution the Society presents the following as the beginning of such a plan:

In the first place there should be a clear understanding as to the extent of the disability permissible to a welder. Good eyesight in both eyes is essential. For metallic arc welding, gas cutting, and carbon arc cutting, a man should have good use of at least one hand. For gas welding and carbon arc welding fairly good use of both hands is necessary or one hand good and one artificial. With regard to the legs, a man working in a shop or at a bench may have any combination of disability provided he is able to get about. But for work on a ship structure or work upon a staging he would be at a disadvantage unless he had the full use of both legs and both hands.

This plan divides itself into two parts, the first relates to learning to weld. The members of the Society have already agreed to keep twenty-five men continuously in training to become welders without cost. This number will increase as the plan becomes more generally understood and as more companies begin to train welders. The Society will aid in placing these men. Further details of this arrangement have not yet been worked out. Any disabled man desiring to learn to weld should communicate with the Secretary of the Society.

The second part relates to the business of independent jobber. Before it could be recommended that a man go into business for himself, he must have shown a capacity for business and must have secured an experience in welding and a knowledge of the subject far beyond that gained by him merely by becoming a competent welder. In such cases as may arise, where these requirements are fulfilled, the Society will assist in setting the men up in this business.

Gas Welding and Cutting During the War

By H. SIDNEY SMITH

WHAT gas welding and cutting did to help win the war in this country and abroad will probably never be fully appreciated. An attempt to detail the ramifications of the metal industry vital to the conduct of the war, into which gas welding and cutting entered as an essential, would be to cover the entire field of industry.

The mechanism of war in this age of steel is really a series of metallurgical problems, whether it be in the production of metals or in the construction of great guns and their carriages, bombs, hand grenades, torpedoes or airships, it is metal everywhere—metal in new and curious shapes and metal in all kinds of combinations. The ore must be mined, the metal produced, formed, joined and severed. So with the outbreak of the war all the metal working industries were stimulated in an unprecedented manner; production had to be doubled and tripled in the shortest possible space of time and oxy-acetylene was a solution which made short cuts possible in construction and repair.

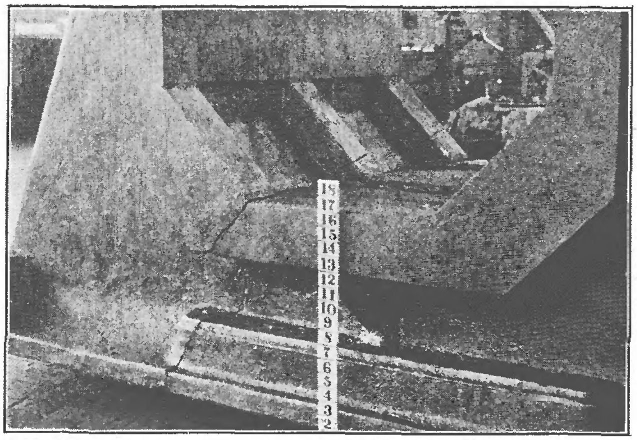

FIGURE 1.—Cracked bed plate of hoisting engine.

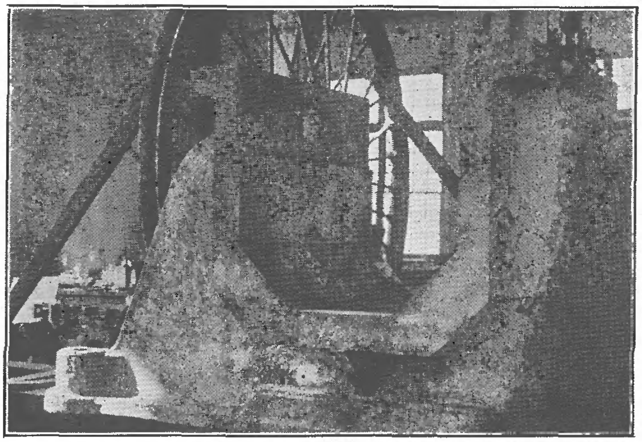

FIGURE 2.—Same bed plate welded.

Mining equipment and handling devices are at all times subjected to extremely rough usage and breakdowns. In normal times plenty of spares are carried and broken parts can speedily be replaced, but during the war, in most cases, spare parts were unprocurable and as a result repair and not replacement had to be resorted to. There are innumerable instances on record of where the application of welding to the repair of an essential part prevented a complete suspension of work. The accompanying figures 1 and 2 are illustrative of the magnitude of some of these repairs.

Figure 1 shows a break in the bedplate under the main bearing of a colliery main hoisting engine.

Figure 2 shows the same bedplate after successful repair by the gas process.

In the steel plants, rolling mills, and foundries equally important work was carried out, and it may not be out of place to describe a few specific instances illustrative of the work.

A welding company in Cleveland in 1918 made repairs on the cylinders of blowing engines used in steel plants in Ohio, where the fractures were 20 to 40 feet long in three inch metal. Work of this magnitude has to be carried on by shifts, in order that when once started it shall go on continuously until finished. The actual welding time on these jobs was 48 to 68 hours. An idea of the aid of these repairs to productivity is better appreciated when it is known that from three to six months would have been needed to obtain spare parts to replace the broken ones, while the repairs made by the oxy-acetylene process were only equivalent to a three hours' shut-down of the plant.

Another important piece of repair work was an 18 by 40 inch fracture in the 70 ton frame of a bulldozer used for shell piercing. The machine was only out of operation 48 hours, while replacement would have taken 40 days. In this case a 38 day output of shells was made possible, at a time when a maximum shell production was of vital importance to success in France.

In another instance repairs were made to the low and high pressure cylinders of a large rolling mill engine at one of the leading steel plants. The low pressure cylinder, shown in Fig. 3, was 5′ 10″ bore, weighing 15 tons, and had cracks in the flange and bore totaling 22 feet in length, in metal 2¾ to 3⅜ inches thick. The actual time taken to chip out the cracks, preheat and weld, was 72 hours. The high pressure cylinder had cracks totaling 4′ 6″ in length in metal up to 6 inches in thickness. These were prepared and welded in 18 hours. Seven days were taken to complete the whole job. It was estimated that the repair cost about one-third of the cost of a new cylinder. This is quite a consideration, but insignificant as compared to the real saving effected when account is taken of the fact that the repairs prevented the laying off of some 350 trained men who would not have been available again when new cylinders had been procured, and also prevented the loss entailed by cessation of production.

In some cases machinery designed for the production of peace time products had to be altered for the production of munitions. This was aided by gas welding. Fig. 4 illustrates the adaptation of a direct driven machine for use in a belt driven plant. Here the pedestal for a pulley bearing is seen ready for welding.

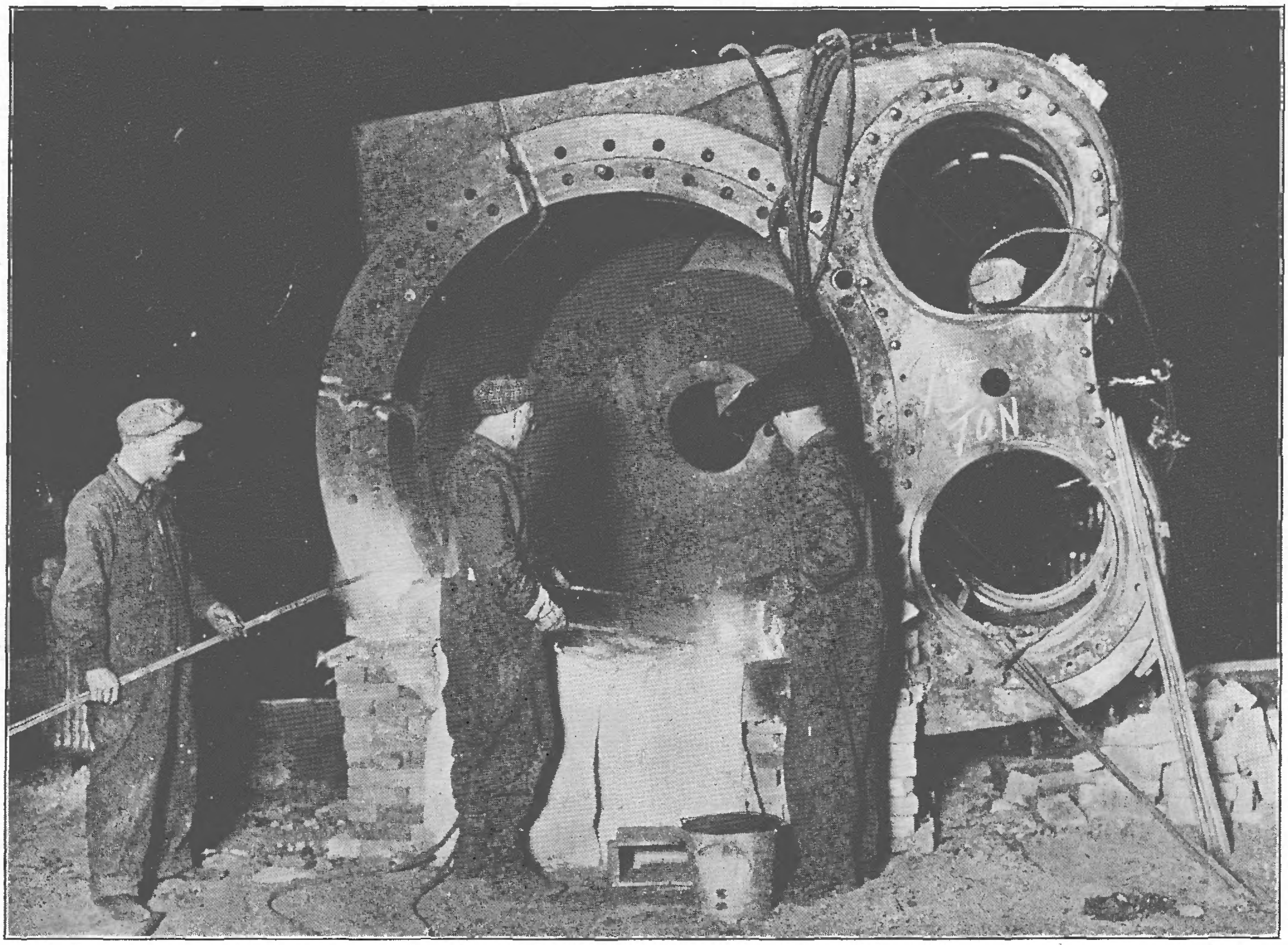

FIGURE 3.—Low-pressure cylinder of rolling mill engine being repaired by welding.

Transportation is a fundamental in the successful conduct of a war and during the hard winter of 1917, when the railroads were at their wits end to keep equipment in running order, and when new equipment was practically unprocurable, the use of acetylene in the railroad shops and in the maintenance of way added enormously to the efficiency of the roads.

Follow transportation to the high seas and we find oxy-acetylene in shipyards again essential. A multitude of new uses in the construction of ships were found and in repairs to marine boilers and other ship parts the savings effected were enormous. In fact, in many cases they were as high as 50 per cent in time and cost over old methods. Some idea of the multitudinous uses to which gas welding can be put in ship construction may be gathered from a perusal of the lists of parts permitted to be welded as issued by Lloyds and the American Bureau of Shipping. In the shipyards the angle-smith of today has little to do but bend to shape the material he is working, as gas performs most of the cutting and all the welding is performed by the gas or electric processes. To a great extent the acetylene blowpipe has supplanted charcoal and oil for heating bent frames, shell plates, stern posts, and other parts under repair. The blowpipe was probably the most important factor employed in speeding up ship production. It was universally employed for shaping plates and cutting the many holes necessary in decks and bulkheads for smoke-shafts, up-takes, pipe-runs, etc.

Gas welding and cutting was an element of extreme importance in converting passenger and cargo vessels, as, for instance, when the Great Lakes' boats were requisitioned for Atlantic service they were cut in two by gas so that they might pass the locks.

At the time the interned German ships were taken over by the Government and found to have had their cylinders and other engine parts maliciously damaged, welding was resorted to as a most effective means to get the ships into commission quickly. Here acetylene welding played a part of extreme importance and the most intricate welding operations were conducted with certainty in result.

Much valuable repair work was done on Lake steamers and while some of this work was being carried out it was clearly demonstrated that extensive repairs could be made on marine cylinders "in situ" which was quite contrary to prevailing ideas in the minds of most engineers. Vertical welding had also at times to be resorted to, and this is another phase of the art which many had thought to be impossible in welding of cast iron. Non-ferrous metals enter very largely into the construction of certain ship parts and fittings and in the repair of such parts gas welding held undisputed sway as the best means to accomplish the desired end. In this line of endeavor some of the most valuable work was done on propellers in building up new tips and edges on blades.

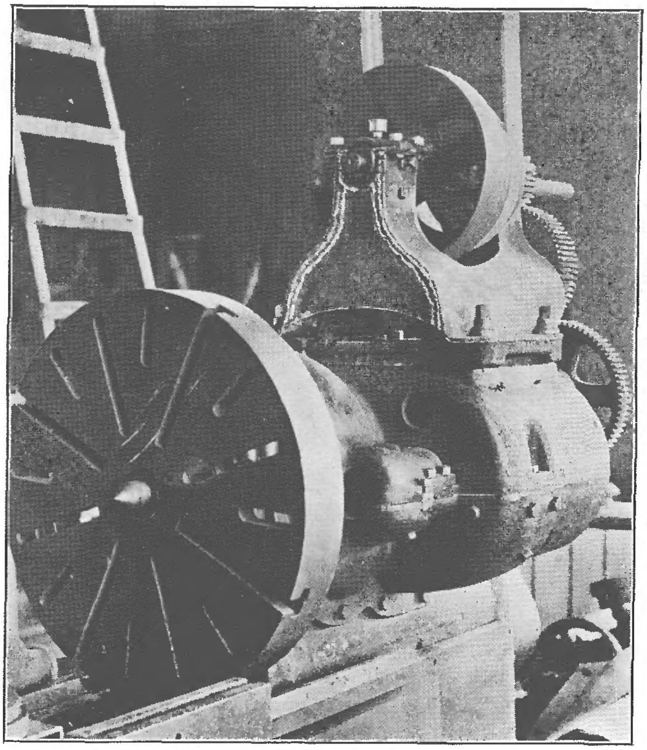

Figure 4.—Lathe adapted for belt drive.

Having followed transportation over the seas, next consider it at the front. Vast quantities of gas welding and cutting equipment, including plants for the generation and compression of acetylene and oxygen, as well as enormous quantities of cylinders, were shipped abroad so that welding could play its part in the important work of keeping the transport system, which supplied our Army, in a state of efficiency. At the base repair shops much extremely valuable work was performed and tens of thousands of cylinder blocks, crank cases, frames, transmission cases and other parts too numerous to mention were made fit for service. Not only was gas welding employed at the base shops but each U. S. Army in France was provided with some 220 machine shop truck units and each of these was provided with gas welding requisites. The work performed by these mobile repair units with gas was of incalculable value. Some of the most valuable work carried out in France was performed by the railroad units and it is frankly admitted by returning officers that if it had not been for gas welding there would have been a serious shortage of railroad equipment. Private Matousek, a welder, received the Distinguished Service Medal for repairing, in four hours at Nevers, locomotive cylinders which otherwise would have been idle for weeks.

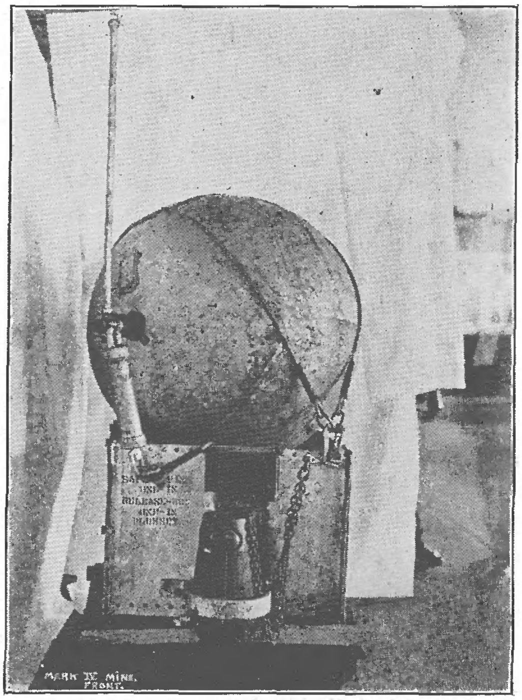

Figure 5.—A mine. Equator seam welded.

Welding work in France rallied for the services of a small army of all-around welders and naturally such men in the quantities required were not to be found amongst the enlisted men, for statistics show that in each 10,000 men drafted into the Army only seven men were welders. This small percentage was due to the fact that a majority of welders were exempted as essential factors in this country in maintaining the military establishment. The few drafted were not sufficient to meet the situation and consequently each branch of the Army started welding schools and quickly trained large numbers of men. The industry was of considerable help in this work and trained thousands of men to meet the emergency.

In the manufacture of engines of warfare gas welding was also extensively used. The mines, which formed an endless chain across the North Sea, preventing the passage of the submarines, had a ten-foot gas weld at the equator seam of each. Fig. 5 shows the mine completed. The welded joint may be faintly seen. Consider what a difficult problem the construction of a metal body of this shape and size would have been if any other form of joint had been resorted to; weeks of time in closing the sea were saved by gas welding when every day meant ships lost.

The depth bomb, undoubtedly the most effective offset to the German submarine, was almost entirely assembled by the use of gas. Longitudinal and circumferential seams and all bushings were welded, as also was much of the interior mechanism.

When the Allies were forced to meet gas with gas and lethal mixtures were developed to the extent that even the minutest mixture with air or a drop on the human body was absolutely deadly, it is very apparent that the apparatus for the manufacture of these frightful substances and the containers in which they must subsequently be transported must of necessity be absolutely gas-tight. In this field of such vast importance not only to our own men but so essential to the destruction of the enemy, the gas-welded joint was apparently the only one upon which complete dependence could be placed, and the confidence that responsible authorities had in the soundness of the gas weld was significant. Figure 6. Possibly the successful production of these poison gases, the enormous potentialities for production on a large scale and the actual shipment of vast supplies—facts known to the enemy—were factors in the hastening of the armistice. Oxyacetylene, therefore, undoubtedly played a part of primary importance in hastening this program and making it more ominous to the enemy.

FIGURE 6.—Making the poisonous gas containers.

In the construction of airplanes gas welding found a vast field of usefulness. The world-famed Liberty Motor had many gas welded parts. The Packard Company in a very interesting communication to the International Acetylene Association gives the following table showing the amount and nature of welding

No. of Welds	*Method*	*Name of Part*	*Inches Welded*	*Total*
2	Acetylene	Water Intake and Outlet	4½	9
2	“	Inlet and Exhaust Valve Cages	8	16
1	“	Bottom circumference of water jacket		27
2	“	Spark Plug Holes	4	8
2	Arc	Inlet and Exhaust Flanges	7	14
2	Acetylene	Valve Stem Guides	4	8
2	“	Camshaft Stud Holes	3½	7
1	“	Vertical Seams		28
				117

The welding work on Liberty Motor parts consisted almost entirely of sheet metal welding and experience has shown that this class of welding requires more skill than does plate welding, yet the Packard Company found that they were able to train welders in their welding school in from two to three weeks for production work and in no case did the training period exceed six weeks. The majority of the Liberty Motor welding at the Packard plant was done by young girls and women and the quality of the work was astonishingly good as compared with the best efforts of the enemy in the corresponding welds in German Mercedes engines.

In conclusion it may be said with certainty that without the gas blowpipe no nation could with complete success conduct modern warfare and that the reasons were multitudinous in justification of the Government's action during the war in giving the highest priorities to ensure production of all gases, apparatus, and materials necessary to permit the employment of an art so important and essential.

Repairing a Lighthouse

By JAMES H. DEPPELER

Thermit is the recognized scientific name for the mixture of aluminum and iron oxide which, when ignited, will support its own combustion and yield iron at a temperature far above its melting point.

DURING the arctic winter of 1917-1918 when zero weather paid frequent visits even to the Carolinas, a most unusual accident happened to Wade Point Lighthouse, which is situated one mile from the shore in Albemarle Sound, N. C. A photograph of this lighthouse is shown on the cover.

NATURE OF THE LIGHTHOUSE INJURY

A large ice-floe which had been formed in Albemarle Sound became detached by a terrific gale and was driven with great force against the five cast iron columns which supported the Lighthouse superstructure over a depth of nine feet of water. So great was the bulk of ice piling upon one side that all the columns were bent through an angle of about 20 degrees and broken. The preliminary bending had pushed the lighthouse structure about 4 ft. off the center.

Figure 1 shows the break in one of the columns.

Fortunately the strong iron tie rods underneath which held the supporting frame together prevented the lighthouse from collapsing. Although the lower part of the broken column had been thrown over into a slanting position the upper part of the structure including the lighthouse proper remained vertical in spite of being offset.

REPAIRING METHODS

The Lighthouse Service was unable until recently to undertake any repairs on the lighthouse. During the first 15 months after the accident no one lived at the light, the lamp being lit by constant visits from shore. At the end of this period a temporary repair was made by driving wooden piles and placing supports underneath the structure.

When the question of making permanent repairs was under discussion, two plans were considered, one for rebuilding the station along its original lines and the other to transfer the present superstructure to a concrete caisson placed close by and secured to the site by piles driven through the bottom of caisson, the structures in both plans to be heavily riprapped. The cost of repairing the lighthouse by the reconstruction of piling was estimated by the Lighthouse Service at approximately $13,000, while the cost of a completely new substructure, upon which the present superstructure could have been moved, was estimated at approximately $30,000. But bids received in both cases were so excessive that it was decided to repair the columns of the old structure by Thermit Welding.

To those who are unfamiliar with the Thermit process, it may be explained that Thermit is a mixture of aluminum and iron oxide. This mixture can be ignited by means of special ignition powder and produce a chemical reaction which results in superheated liquid steel and slag (aluminum oxide), at a temperature of approximately 5000 deg. Fahr. This Thermit steel is sufficiently hot to melt and dissolve any metal with which it comes in contact and amalgamates with it thus forming a solid homogeneous mass when cool. In making welds by the Thermit process the parts to be united are surrounded by a mold and the sections heated red hot by means of a special preheater, after which the thermit steel is poured into the mold.

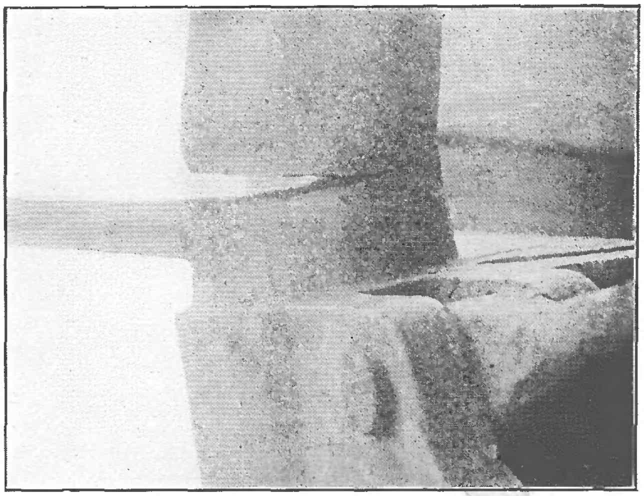

FIGURE 1.—All the cast-iron columns that support the lighthouse were broken. This is one of the breaks.

Owing to the isolated situation of the Lighthouse all welding materials plant and working party were transported from Norfolk, Va., by a small steamer which was moored by the Lighthouse during the welding operation and served as quarters for the repair men.

JACKING UP THE LIGHTHOUSE

The first operation consisted in jacking up the superstructure in order to remove the weight from each column successively, as it was being welded, also to control the allowance for contraction of the weld. As the jacks on hand proved to be too light to support the lighthouse it was necessary to obtain a 50-ton ratchet jack from Elizabeth, N. C., the nearest available place.

The lighthouse was jacked up as follows: two 8″ x 8″ timbers were laid side by side near the corner of the house and across the top of the iron tie rods which connected the columns together. The jack was set on these timbers and on the head of the jack was placed a wooden structure 10″.x 10″, which in turn supported an oak cross beam on which 15″ I-beams supporting the lighthouse rested. To prevent sideplay when the jack was raised, the structure had to be further secured in place by means of chains. This structure above the jack was lifted during each weld so that the upper part of each broken column was raised 3/16″ as an allowance for contraction. The jack was lowered gradually during the first and second hours after pouring each weld until the column finally supported its entire original weight.

Having jacked up the column the next step was to cut out about a 1½″ gap between the broken sections, to allow space for the Thermit steel to enter. Since in each case the inclination of the lower part of the column had already provided a sufficient gap half way through this section (except in one case where the column had snapped back into place), it was only necessary to drill a series of 3 3/8″ diameter holes each ½″ apart by means of an electric drill with power supplied from a dynamo on the steamer, then knock out with hammer and chisel the metal remaining between the line of holes and the break.

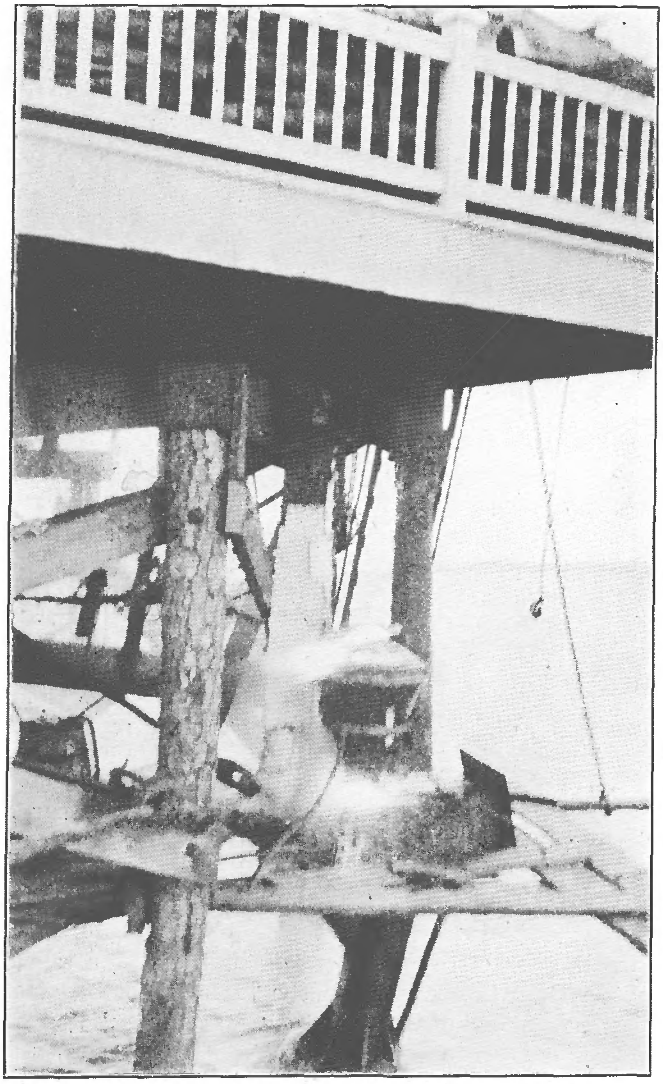

Figure 2.—Pouring the Thermit steel.

CONSTRUCTING THE MOLD

As the columns were hollow with 1½″ thick walls, the interior had to be filled with molding and facing sand for the steel mold, for a depth of from three to five feet below the weld at which point a flange extended horizontally through the columns. First it was necessary, however, to remove about 2 ft. of water which had collected in these spaces through rise and fall of the tide in order to prevent steam from being formed from the heat generated by pouring the molten steel in the weld, and injuring the mold. An oval hole 2″ wide and 3″ long was therefore drilled out of the column about 15″ above the break and the water removed through this hole.

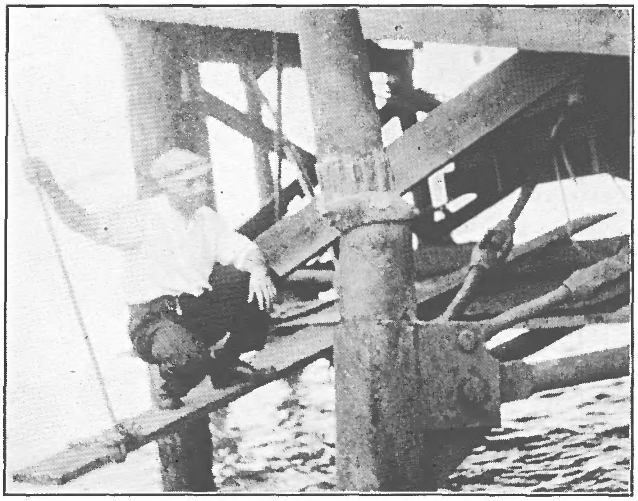

Figure 3.—One of the completed welds. The columns were purposely left offset.

Packing the molding sand inside the column was also a slow performance as the ramming had to be done with a bent rod inserted through the hole without the interior being visible to the operator, whose working facilities were cramped by the peculiar construction of the lighthouse, and consisted at times of only a board suspended by ropes from a railing about as shown in Figures 2 and 3. When the upper section was rammed up, rope was wrapped around the break to prevent escape of sand. Facing sand was inserted for 6″ above and 6″ below the break. After the column was rammed up to a height of 1 ft. above the break, the sand at the break was removed with a trowel and yellow wax applied to form a pattern for the mold. This wax, which is later melted out, preserves the space to be occupied by the thermit steel. The wax was inserted 1½″ inside of both upper and lower sections and shaped around the outside of the break in the form of a tapering collar 6″ wide and ¾″ thick at its center. In constructing a mold box the base consisted of two plates fitted around the column and supported partly by tie rods and partly by 3 knee-irons bolted to the column. The mold box was 18″ deep, 24″ wide and 36″ long, its length being supplied in order to project under a crucible. The pouring gate pattern was set diagonally outwards while two heating gate patterns were placed horizontally against opposite side of the wax pattern in order to give proper circulation to the preheating flames.

Four wooden riser patterns consisting of wooden blocks 10″ long and of 1½″ x 3″ sections were inserted with bevelled edges against the wax pattern and slanting upwards and outwards. Additional riser patterns in the form of small pieces of wood 1¼″ thick and 1″ wide were placed against the column vertically above the wax for the purpose of preventing the walls above the weld from sloughing away, also to afford escape of gases.

The sections are preheated by means of 2 kerosene torches supplied with compressed air, from apparatus on the steamer. The object of preheating was to heat the adjacent sections to a temperature sufficiently high to provide a more uniform contraction when the weld cooled. The preheating took in each case from 2½ to 3 hours.

POURING THE THERMIT STEEL

The lighthouse was amply protected from any possibility of catching fire during the repairing by shielding all exposed parts in the house with asbestos sheets. The crucible used for the reaction was supported on a tripod, the feet of which rested on the temporary wooden staging. The welds required from 125 to 175 lbs. of Thermit, according to the size of opening cut out, making a total of 750 lbs. for the 5 columns. Figure 3 shows the completed weld. When the crucible was set securely in place over the pouring gate of the mold, the ignition powder which lay on top of the thermit in the crucible was ignited and the thermit reaction thus started. In spite of the intense heat of the reaction no injury occurred to the lighthouse structure. Each weld was allowed ample time to cool after which the mold box surrounding the weld was dismantled and the excess metal left by the pouring and heating gates and risers was cut off.

It will be noticed in the illustration that the columns were welded together in their leaning position, no attempt having been made to straighten them, as it was impossible to force the piles back to their original position and the cast iron columns could not be bent.

The actual time consumed in making the 5 welds was a little less than 3 weeks.

The Effects of Heat on Iron

*An Abstract of a Few Secrets of the Metallurgist Simply Told**

By GERALD. W. HINKLEY

The subject of Metallurgy is so thoroughly involved in welding that a statement of its elementary principles will be useful to welders. The reader may desire to refer to the amount of carbon in commercial steels, which is as follows:

	Carbon
Welding wire and welding electrodes contain	.02 *to* .40%
Wrought iron	.02 *to* .05%
Ordinary plate (tank steel)	.15 *to* .18%
Structural steel	.20 *to* .25%
Ship plate	.20 *to* .30%
Destroyer plate	.25 *to* .35%
Cast steel	.20 *to* .30%
Cast iron	2.75 *to* 4.00%

WE live in a world in which certain conditions of the atmosphere and the elements surrounding our daily existence are entirely familiar to us. From force of habit we are likely to forget that if it had been planned that we could live under a different range of temperatures, all the familiar objects of our daily existence would have existed under entirely different forms.

For instance, if the normal temperature had been about 2700 degrees Fahrenheit instead of about 60 degrees Fahrenheit and we had been constructed so that we could comfortably endure that degree of temperature, we could have gone sailing on a sea of molten iron, in boats built of plumbago crucibles and oars made of silica brick. Under these conditions we could place frozen lumps of our sea of iron in our ice boxes for refrigeration. Flatirons and stove lids would therefore have been the products of the ice man. The water with which we are now familiar, of course, could not exist in its liquid form, or even as steam, but instead as a highly gaseous state, which we would probably have been called upon to breathe.

If we can imagine ourselves therefore as existing under the relative conditions described above, which once were the natural conditions of the earth and undoubtedly are now of some other world, we can understand more clearly the forms of iron and steel that differ from those with which we are at present familiar.

One of the first physical changes which we would discover would be that when we desired to "freeze" our iron water, we could do so much more easily if it were in an absolutely pure state than we could if it were mixed with some other element, such as carbon. Of course, we have long known that this is the case with water and salt, and just as it becomes harder and harder to freeze water with greater and greater percentages of salt mixed with it, so the freezing of iron

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with greater and greater percentages of carbon mixed with it, would also occur at lower and lower temperatures (i. e., the melting point is lower).

If we started to add salt to a pail of water, we, of course, would have different strength of brine. Just so with the addition of carbon to a crucible of pure iron, we would likewise have different degrees of the resulting mixture. Finally in adding the salt to the pailful of water, we would arrive at a point where the water had absorbed all of the salt which it was capable of holding at the temperature. If we had added a little less salt we may consider for the sake of the analogy that we would have had free water in excess of salt, and if we had added a little more salt it would have been impossible for the water to have dissolved it, and we would, therefore, have had salt in excess of water.

For convenience we will call the mixture at which the water becomes thoroughly saturated with salt, "cementite," because this is the name the metallurgists have given to a similar mixture of iron and carbon. They call the water "ferrite," the salt "carbide," and the resulting mixture of brine "cementite." This mixture always exists as 93.4% iron and 6.6% carbon. It is a chemical compound, carbide of iron, and is expressed by the symbol Fe_3C. Now let us go back to the brine solution and suppose that we added a little more salt than the water could absorb and bring this mechanical mixture to such a low temperature that it would freeze. We should then find a new compound which is regarded as a separate and distinct constituent of steel, and takes the name "pearlite" from its pearl-like appearance under the microscope. Pearlite contains approximately 0.9% carbon and consists of interstratified layers or bands of ferrite and cementite. [NOTE:—The analogy is not exact here. Fig. 4 shows better how the cementite and the pearlite exist in a piece of steel.]

Let us now amuse ourselves for a while by running through a little experiment with a piece of steel containing 0.9 carbon. For our investigation we will also need a special kind of thermometer for measuring high temperatures. Such an instrument is known as a "pyrometer." Now we will drill a little hole in the test piece of carbon steel and after inserting the "couple" of the pyrometer into it, place the same in the electric furnace.

As the current is turned on, the test piece grows warm, then hotter and hotter, gradually up through a range of temperatures, which are continually recorded

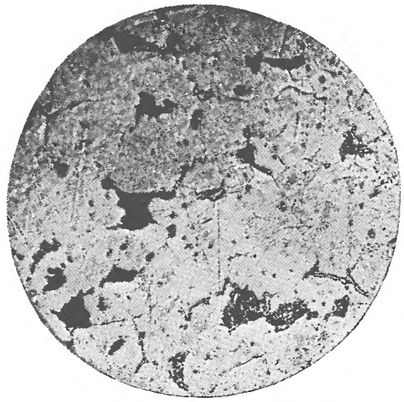

FIGURE 1.—Steel containing 0.11% carbon, light portion—Ferrite; dark portion—Pearlite; magnified 500 diameters.

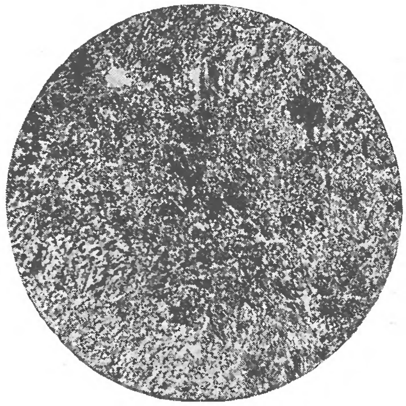

FIGURE 3.—Steele containing 0.9% carbon, fine uniform Pearlite condition, magnified 500 diameters.

FIGURE 2.—Steel containing 0.37% carbon light portion—Ferrite; dark portion—Pearlite; magnified 500 diameters.

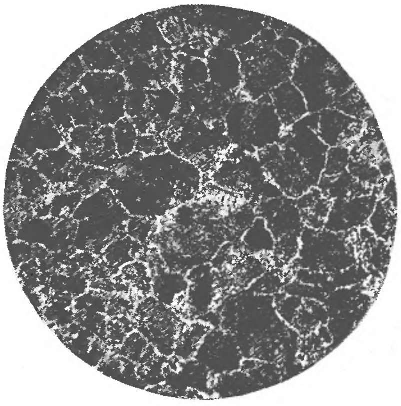

FIGURE 4.—Steel containing 2.0% carbon, dark portion—Pearlitic; white boundaries—Cementite; magnified 500 diameters.

by the needle of the pyrometer. 800, 900, 1,000, 1,200 degrees Fahrenheit are uniformly reached, and the temperature of our test piece continues to rise, as the absorption of heat progresses. Suddenly, however, although the heating continues the needle of the pyrometer ceases to advance, and we note that it is pausing at about 1350 degrees Fahrenheit. Then after its pause, the advance is again resumed until the piece has become almost ready to melt.

Now let us begin to cool off our test piece gradually. The temperature of the furnace is lowered and the range of cooling temperature is recorded by the ever sensitive needle of the pyrometer. Suddenly the test piece assumes a brilliant glow, and again the needle comes to rest, but this time we note that the recorded temperature is about 1250 degrees Fahrenheit. Evidently there has been a certain tardiness or "lag" which has caused the phenomenon to take place a little too high going up, a little too low coming down, and in fact the metallurgists tell us that such is exactly the case, and that the real point in which we are interested lies just half way between the two points indicated, as we shall presently see. Figure 5 is a graphical representation of this action.

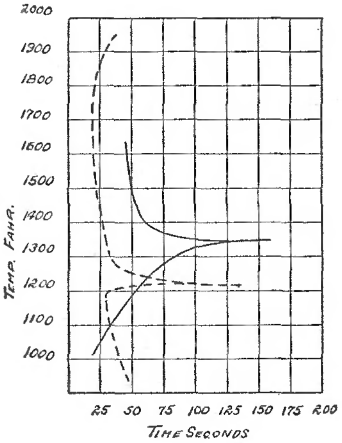

FIGURE 5.—The critical range in steel containing 0.9% carbon is between 1,250° F. and 1,350° F.

It is natural to suspect that both of these points have something to do with the same thing, and for convenience since we noticed that mysterious glow of the test piece just as the needle came to rest, we might call the particular point which lies just half way between the temperatures under discussion, the point of glow, or "recalescence," and the range between these two temperatures the "critical range."

I suppose it would be difficult to explain this phenomenon of the test piece unless we imagine that as the critical range is reached some internal reaction of the steel causes it to spontaneously take on heat at the same temperature in the first place and give off the stored heat at the same temperature as the piece was being cooled down, and this heat caused it to glow as was noticed. Now if we were to experiment further with our piece while at the critical range, we would find certain other remarkable changes, one of the most noticeable of which is the loss of magnetism at and above the critical range.

Irons and steels are usually the most magnetic materials, but the attraction of the magnet is completely lost at or above the critical range.

Let us just consider this phenomenon a moment We are told by the physicists that magnetism is induced in a piece of iron or steel by a rearrangement of the internal molecular structure, in which the positive ions face one direction and the negative ions in the opposite direction. Therefore, if magnetism suddenly ceases to exist it would seem as if something had happened to the "internal molecular structure" of the test piece. Thus when the critical point is reached we may conclude that something more than a mere absorption of heat units has taken place. In fact we may really believe that an actual internal molecular revolution has occurred and that some of the natural laws which formerly had governed all of these little molecules which go to make up the whole piece of steel have been overthrown and that the molecules are more or less free to set up a new form of government for themselves, and that, therefore, when a piece of steel is brought to this point it is really in a very sensitive condition. If we should care to investigate further we should find that certain other great changes take place at this critical point, such, for instance, as partial failure of the test piece to conduct an electric current, which formerly, of course, it did with great ease. Also when the critical range is reached, a peculiar contraction of size interrupts the gradual expansion which had been developing as the test piece absorbed heat units, and therefore these several observations give us reason to believe that our conclusions as noted above must be more or less correct.

Now if all steels acted exactly like the little test piece which we have been observing above as they were placed in the hardening furnace, it would not take us very much longer to finish our preliminary investigations. You remember the piece of steel which we have been investigating was a piece of simple carbon tool steel, containing about 0.90% carbon. But all steels do not contain just this same percentage of carbon, and may also contain various elements other than carbon, all of which produce many and varied results during the process of heating, treating and hardening.

Let us go through the same experiment with a piece of steel containing .45% C. Just as before, as the temperature 1250 degrees Fahrenheit is reached we note all the strange symptoms which are characteristic of the point of recalescence and then, just as we are about to decide that it is hardly necessary to go further, we notice that the pyrometer needle has again come to rest, but that this time it is registering 1390 degrees Fahrenheit. Therefore, it would seem as if this piece had two critical ranges instead of one.

Now let us take a piece of carbon steel as before, but this time containing .15% carbon, and again proceed with our observations. Again the needle of the pyrometer records the point of recalescence and also the point designating the second range of critical temperature, but this time, strange to say, as the test piece continues to absorb heat, a third critical range is registered.

By repeating the operations as outlined above, with pieces of steel containing various percentages of carbon from zero to 1.25% and by plotting the different critical temperatures so obtained, we finally obtain a chart Figure 6, which graphically expresses the critical ranges of iron and steels due to the variation of the carbon content.

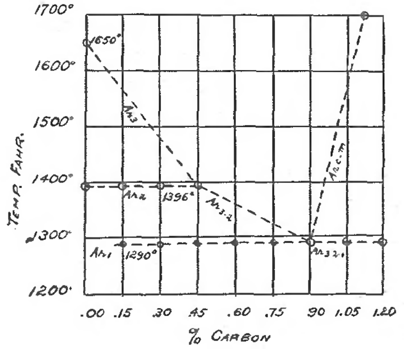

FIGURE 6.—The critical points in steels containing various amounts of carbon.

Now, as we concluded before, it is evident that some internal change must have taken place in the steel itself, and as we know that the chemical content does not vary, it is further evident that the change must be of a physical nature, or as in the language of the metallurgist, an "allotropic change."

There is one very fortunate circumstance connected with the passing from one of these allotropic changes to another, and that is that the effecting of one of these changes takes time. It does not take a very long time, however, for in some instances the change is affected in a very small fraction of a second, while rarely more than one or two seconds are required.

Would it not be interesting if we had been so constructed as outlined in the beginning of this little volume; that we could have withstood the high temperatures in which some of these very interesting changes occur, because we could then handle the steel, examine it and experiment with it at our leisure. However, such not being the case, we will have to derive some other means for "catching" the steel while it is in one of these interesting conditions, and then bringing it in its entrapped condition down to room temperature. How shall we do it? Well, we remember that we said it took time to effect the changes under discussion and furthermore we remember that the changes can only take place when the steel is within the proper critical range. Therefore, if we could do something to lower the temperature of a piece of steel while in one of the critical ranges before the steel had time to effect the usual allotropic change of form, we might be able to catch a piece of steel while in one of these unusual conditions, before it had really had time to get back to normal.

Therefore, let us place a piece of .9% carbon tool steel in the heating furnace and bring it up to and beyond the point of recalescence. Now, grasping the piece firmly in a pair of tongs with all possible speed we plunge it into a nearby pail of ice water, keeping the steel constantly in motion. Almost instantly the steel becomes black and within a few seconds is actually brought down to room temperature.

Now let us take the steel out and examine it. The act of tapping it on the anvil in order to knock off the surplus water gives us a hint that our test piece has undergone some sort of a change. For now it rings with a bell-like clearness and gives the hammer with which we strike it a quick snapping rebound which in itself indicates great hardness. Next, we test the piece with a hardened steel file with which we could easily have made a deep groove before we attempted the heating operation and to our surprise the file has as little effect as if it had been made of wood. And to our surprise on closer examination, we actually find that our test piece has scratched the file—surely it must be very hard. We are convinced that some marked change must have taken place. What can it be? Why it must be that due to the rapid cooling in the pail of ice water we brought the temperature of the test piece down below the critical range before the abnormal condition at which it existed while at and above the critical range had found time to change back to its former condition. And we remember that if one of these allotropic changes is going to take place at all, nature says it must do so while the steel is within the critical range and therefore having forced the steel through that critical range which separates one allotropic condition from another, before it had found time to effect its desired change, we managed to entrap the abnormal condition so that we could see it and feel it and get familiar with it at room temperature.

Now let us take our test piece to the grindstone and grind it down to the shape of a cutting tool. It is necessary to resort to the grind stone, in order to get the desired shape, because of course, our test piece is far too hard to cut with any other metal. After having produced a tool of the desired shape and size, let us fasten the same securely into the carriage of a lathe, and then upon applying the cutting edge to a revolving piece of cast iron, or soft steel, or even to a piece of the very same grade of steel out of which the tool was made, only while it is still in the softened or annealed condition, we find that it is capable of easily and quickly cutting out a good sized ribbon of chips from the metal which is to be machined.

However, we are soon confronted with a new difficulty, for as the cut progresses, our tool runs into a rough spot which causes it to tremble and chatter and then suddenly our tool cracks in two in the middle and is at once completely ruined.

It is evident that as we are able to increase the desirable element of hardness in a piece of tool steel, we also automatically increase the undesirable element of brittleness, and therefore some new method must be devised which will allow a sufficient degree of hardness to allow the tool to cut other metals and at the same time not cause so much brittleness that it will crack in two at the first rough spot which it encounters.

One method of assisting the toughening of a piece of hardened tool steel is accomplished by the process of "drawing." This simply means heating the piece of hardened tool steel up to some fairly warm temperature, which of course must be kept well below the critical range (at which the steel would jump at the chance to quickly change back into one of its softer allotropic forms) and then keeping the steel at this drawing temperature for a while until the unusual strains and stress caused by the rapid cooling have had an opportunity to have become somewhat relieved. Therefore, the process of "drawing" is quite as important as is the first act of hardening itself, and great care must be exercised in undertaking the same.

(*Comment by S. W. Miller.* The welder will see from this article how the knowledge of steel applies also to welding. Although much of the carbon burns out and is therefore low in the completed weld, the same changes occur in welds during their cooling as in the cooling of a piece of steel of the same carbon content. It is, therefore, desirable for the welder to be familiar with the changes that take place in iron or steel due to the heating.)

The Need of the Gas Welding Industry

By M. KEITH DUNHAM

Lack of attention to elementary principles of oxy-acetylene welding is probably responsible for most of the failures. Apparently the real crying need of the industry is education.

1. As to the importance of fusion — not adhesion.
2. The absolute necessity of understanding expansion and contraction.
3. The necessity of educating the engineer as well as the welder in the fundamental principles of Oxy-Acetylene Welding.

All over the country good work is being done daily by good welders, — men who have grasped and applied these principles, — and all over the country poor work is being executed by poor welders. If we can give to these poor welders the knowledge of the good welders we will have made a rocket stride forward.

It would seem that the proper instructor for the welder is the man who has had both the practical and technical experience, and if choice was necessary, practice is the more desirable of the two requirements. For example, a short while ago the writer visited a welding school where the instructor impressed the students with the importance of paying attention to expansion and contraction and used the well-known broken spoke of the gear wheel as an illustration. But he gave reasons for pre-heating the rim, which a practical welder who had tackled a job of this kind before, would know instantly were based on things that could not possibly happen.

If no attention is paid to the law of expansion and contraction, failure, except on the simplest welding jobs, is almost certain.

Time after time oxy-acetylene men have been up against the problem of trying to educate the engineer of a plant to lay out his welding work in accordance with welding practice. Many times the welder is up against the problem of making a weld on a receiver or tank, which has been designed for riveting and it is one of the hardest jobs in the world to convince a man unfamiliar with welding of the importance of laying out his work so that the welder can make a successful job. The oxy-acetylene industry in the past couple of years has been inundated with technical articles as to what takes place in the weld. Writings and research work are of the utmost value to the industry, but the real need of ninety nine out of a hundred welders and engineers is simple principles simply explained — the A, B, Cs of welding.

Safe Practices for Gas Welding and Cutting Equipment

Two very complete sets of rules and regulations have been compiled by the National Safety Council and the National Board of Fire Underwriters with reference to the proper use of gas Welding and Cutting Equipment. The rules present in an orderly manner the safe installation and use of such equipment.

The titles of these pamphlets are Safe Practices — Gas and Electric Welding issued by the National Safety Council and regulations of the National Board of Fire Underwriters for the Installation and Operation of Acetylene Equipment. They may be obtained without cost by applying to the Secretary of the Society.

American Bureau of Welding

The Directors of the American Welding Society at their first meeting on March 28, 1919, invited certain other societies and governmental departments to join them in the formation of the American Bureau of Welding. The completion of the organization of the Bureau was delayed in order that the representatives could be officially appointed and take their part. The Bureau is, therefore, only just ready to begin its work, and some of its committees have not yet been appointed.

The work of the Bureau is conducted principally through its Research Committee, only matters for final approval coming strictly before the Bureau itself. According to the by-laws the membership of the Research Committee is not confined to members of the Bureau. Thus the services of anyone who can contribute to its work may be obtained. The National Research Council have taken this Committee as their Committee on Welding. So it now acts in connection with both bodies.

The first task undertaken by the Research Committee was to prepare a summary of the work of the Welding Committee of the Emergency Fleet Corporation. For this purpose a sub-committee was appointed whose report will be presented in the Journal, in parts, as fast as it is prepared. Mr. Lemp's introduction appears in this issue. Prof. Hudson's Theory of Arc Welding is also a part of this work.

Besides this, the Bureau has taken up two questions which are of the greatest importance in welding. The first, what shall constitute the test of a weld; the second, how welders shall be trained. A committee had been appointed on each of these subjects, and their reports will be taken up immediately.

The Work of the Welding Committee of the Emergency Fleet Corporation

By HERMANN LEMP

THE Welding Committee of the Emergency Fleet Corporation, which, under the chairmanship of Professor C. A. Adams, during the war emergency, has been of notable assistance to that Corporation and to the welding industry as a whole, had its origin in a Sub-Committee on Electric Welding formed from the Standards Committee of the American Institute of Electrical Engineers, which met for the first time July 24, 1917, at the Massachusetts Institute of Technology, at Cambridge, Mass. At this meeting spot welding—a modified form of electric resistance welding as originated by Professor Elihu Thomson—was proposed for welding ship plates, in place of riveting, to expedite construction of ships. As a sequel to this meeting, it was suggested that, in addition to spot welding, arc welding in connection with spot welding should be investigated.

At the second meeting a communication was received, transmitted from U. S. Shipping Board through the Engineering Committee of the Council of National Defence, requesting information and advice as to the most economical methods of producing anchor chains in large quantities. A sub-committee, under chairmanship of Mr. W. L. Merrill, consisting of representatives of chain manufacturers, Navy Department, Classification Societies, U. S. Steam Inspection Service, and the Emergency Fleet Corporation, was appointed to solve this problem, and the result obtained will always stand as a monument to the foresight and clear judgment of this group of men, who in a short space of a month and a half produced a sample chain, and within six months started production on an order of $1,000,000 for chains made by a new process, which saved the Government $50,000 at the start. This result is all the more noteworthy, as most articles manufactured under war pressure increased rather than decreased in price. The new chain, made from cast steel, refined in an electric furnace, not only met the specifications of the carefully hand forged chain of the past, made by skilled help, but surpassed it, so that the

Classification Societies, reluctant at first to accept it, increased the test requirements 40% above that of the old hand forged chain; but more important than all this, the process so far outdistanced the antiquated methods of making chain, that in place of the average production of a gang of chain welders of the highest skill of less than 1000 lbs. per day, a foundry unit with a 10-ton electric furnace produced 70 tons of two-inch chain in 24 hours, by mostly unskilled labor.

At the same meeting plans for spot welders of the portable and stationary type for from one-half inch plate up to one-inch ship plates were discussed.

On February 21, 1918, a small committee was appointed by the Emergency Fleet Corporation of the United States Shipping Board, consisting of E. A. Stevens, Jr., A. J. Mason, D. B. Rushmore, and C. A. Adams, chairman, with the request that it expand to take in all necessary interested and to thoroughly investigate electric welding in connection with ship building. This committee was attached to the Division of Steel Ship Construction, under the general direction of Mr. D. H. Cox, manager of that division, and its accomplishments were due in large measure to his wise guidance and backing. The first meeting of this committee was held Saturday, March 23, 1918, at the headquarters of the American Institute of Electrical Engineers in New York.

At the request of the Emergency Fleet Corporation, Capt. James Caldwell, of the Royal Engineers, was sent by the British Admiralty to stay three months in this country to give their experience with electric welding, as applied to shipbuilding. Capt. Caldwell stated that in England, since the war broke out, the demand for gas for oxy-acetylene welding was so great that electric arc welding was taken up as a substitute. Capt. Caldwell since then has written a complete report which has been published by the Emergency Fleet Corporation and was reviewed by Professor Adams in the *Electrical World* of September 7, 1918.

Contrasted with the British experience, as explained by Capt. Caldwell, American engineers were seriously considering spot welding in place of riveting. The most radical and interesting proposal in this connection was due to Mr. A. J. Mason of the United States Shipping Board. It was to employ a large portable spot welder for assembling and tacking the ship plates, after which they were to be arc welded. As a result of Mr. Mason's efforts, the Emergency Fleet Corporation authorized the building and testing of a 42-foot midship section of a 9600-ton ship by this method. All preparations had been made and the portable spot welder was almost complete when the work was stopped by the signing of the armistice. Had this experiment been carried to a successful conclusion, it would have demonstrated a great saving in hull construction.

At the meeting of April 23, the question of testing methods of welded ship parts was reported on without arriving at any final conclusion.

At the fifth meeting, April 29, 1918, the Ship Design Committee presented full specifications and drawings of a 10,000 ton electrically welded ship with yard and equipment necessary to build it. This design was of a radical nature, utilizing electric welding, both the arc and spot type exclusively, and departed from existing methods of building ships, carrying the fabrication idea to a further degree than had yet been attempted. The Welding Committee was in favor of having such a ship built at the earliest possible moment. The very boldness of this proposition acted as a stumbling block to its ready acceptance by the more conservative elements in the United States Shipping Board, and requests were made that specific costs and possible deliveries of equipment, and number of trained men available for welding should be submitted before the building of such a ship would be authorized.

For the purpose of informing shipbuilders, four district meetings were held as follows:

First District—March 18, 1918, in the office of the District Officer, Boston Custom House.

Tenth District—March 21, 1918, in the office of the District Officer, Medical Arts Building, Philadelphia, Pa.

Second District—March 26, 1918, in the office of the District Officer, 115 Broadway, New York.

Third District—March 29, 1918, in the office of the District Officer, Mexington Building, Baltimore, Md.

At these meetings, Professor Adams and Capt. Caldwell thoroughly explained the possibilities of electric welding as applied to ship building and the results already achieved, and the prospects of further applications.

These meetings were followed by a series of lectures in Philadelphia, given under the auspices of the Emergency Fleet Corporation, under the chairmanship of Mr. H. A. Hornor, and which were intended for the men in the shipyards.

Wed., 8 P. M. June 26, 1918	Naval Constructor H. G. Knox, U. S. N. "The Language of Electric Welding"
Wed., 8 P. M. July 10, 1918	W. L. Merrill "Tools of Electric Welding"
Wed., 8 P. M. July 17, 1918	J. H. Anderton "Time Saving in Steel Ship Construction"
Wed., 8 P. M. July 24, 1918	E. J. Rigby "The Boiling Rod"
Wed., 8 P. M. July 31, 1918	H. J. Cox "Design of Ship Joints"
Wed., 8 P. M. Aug. 7, 1918	Prof. Comfort A. Adams "Summary of the Work"

These meetings were well attended and later a request was made that the addresses and discussions should be printed and distributed.

Under the leadership of Mr. H. M. Hobart, the Research Committee investigated the current density suitable for various electrodes; non-destructible methods for testing welds; effects of locked up stresses in welding long sections by rigid or non-rigid methods of holding plates during welding; effects of corrosion on welds and adjacent metal, and conducted a series of tests on one-half inch ship plates welded by representatives of welding apparatus; the choice of electrodes, current density and method of control being left to the discretion of the welders; and finally submitted standard methods for testing electrodes for welds of all kinds, and revised specifications for electrode wire. These tests, known as the Wirt-Jones tests, were conducted mainly at the Bureau of Standards in Washington under the direct supervision of Prof. H. L. Whittemore.

Especially noteworthy was a large test tank built under the supervision of Mr. R. E. Wagner, Pittsfield Works of the General Electric Company, by the non-rigid method, in which all the various joints proposed to be used in the 10-ton electrically welded ship were represented. This tank was hydraulically tested, showing conclusively that receptacles and tanks could be made water and oil proof to better advantage by welding than by riveting.

A method of ship construction, proposed by Mr. F. M. Hill, was to make up the ship from cast steel-sections to be welded together. He showed some interesting results of steel castings produced by the Snyder electric furnace at cost of three cents per pound.

As a result of the instruction propaganda, the Ship Yard Visiting Committee reports that at Hog Island alone hundreds of thousands of parts were being welded instead of riveted, in which the saving is approximately 70%.

At the July 16, 1918 meeting a resolution was passed to enlarge the scope of the Electric Welding Committee by including in the personnel representatives of all other welding methods, principally gas and thermit. The reorganization took place in September under the name of the Welding Committee.

At the August meeting a summary was presented of the experiments made by Lloyd's of England to test the trustworthiness of structural connections made by electric welding. Also a report on electric welding a steel barge in England. Reference is also made here for the first time to a 42-foot tug electrically welded throughout, built by the Geary Boiler Works, Astabula, Ohio, and in service for about three years on Lake Erie.

At the September meeting the Research Committee recommended the building of a complete electrically welded ship of not less than 3500 tons.

In October Professor Adams reported that Mr. Schwab was interested in the building of a completely welded ship of standard design, and in reply to his request the following recommendation was made: Size of ship, 5000 tons, to be made of one-half inch plates, and built in the Submarine Boat Corporation yards with material on hand. Estimated cost $1,290,000.

In view of the signing of the armistice not only the building of the 5000-ton welded ship was rendered unnecessary but the continuance of the Welding Committee as a part of the Emergency Fleet Corporation became doubtful. Steps were then taken, resulting in the formation of the American Welding Society, whereby the accumulated work of the committee might be made available to American industries as a whole during the peace reconstruction period. It was greatly regretted by the committee that the work on the Mason Section should at this moment be abandoned when a relatively small sum of money would have been sufficient to bring this matter to a conclusion.

The writer feels deeply grateful for having had the opportunity to sit around a council table with so notable and earnest a group of men as composed the Welding Committee of the Emergency Fleet Corporation so truly representing welding in all its branches. He sincerely hopes that the spirit of co-operation shown by the willingness to lay the cards on the table and unselfishly share with all hard-earned personal experience which was prompted by patriotic motives under the stimulus of destructive war, will be continued to an even greater degree during the more important period of constructive peace now ahead of us.

In conclusion, attention is directed to the following papers read before engineering societies, and reports and articles by members of the Welding Committee.

Electric Welding and its application in the U. S. to ship construction by Capt. Jas. Caldwell, R. E. to United States Shipping Board, 1918.

Notes on Welding Systems by Capt. Jas. Caldwell, R. E. read before institution of Engineers and Shipbuilders in Scotland, 1917-18.

Condensed summary of Capt. Caldwell's report by Prof. C. A. Adams in the *Electrical World*, Sept. 7, 1918.

Electrically welded cargo ships in *Nauticus* of June 1st, 1918.

Welding Mild Steel, paper by H. M. Hobart, before American Institute of Mining Engineers, New York, February, 1919.

Fusion in Arc Welding by O. H. Escholz, read before American Institute of Electrical Engineers, February 19th, 1919.

Path of Rupture in Steel Fusion Welds, by S. W. Miller before American Institute Mining and Metallurgical Engineers, February, 1919.

Application of Electric Welding to Ship Construction by H. J. Cox before Society of Naval Architects and Marine Engineers, 1918.

Welding as a Process in Ship Construction by S. V. Goodall, R. N., American Institute of Electrical Engineers, March, 1919.

Training Welders and Cutters.—Fred E. Rogers, *Acetylene Journal*, August, 1919.

Oxy-Acetylene Welding Schools, Motor Transport Corps, Major C. K. Bryce.—*Acetylene Journal*, October 9, 1919.

Uses of Oxy-Acetylene in Ship Construction, by H. I. Walsh, Newport News Shipbuilding & Dry Dock Co.—*Welding Engineer*, Sept., 1919.

Uses of Acetylene in the Navy Yards, by Lieut.-Com. H. G. Knox.—*Welding Engineer*, Oct., 1919.

The *General Electric Review* for December, 1918, contains:

Electric Welding in Shipbuilding, by C. A. Adams.

Welding in Hulls of Ships, by H. M. Hobart.

Electric Welding in Navy Yards, by Lieutenant-Commander H. G. Knox.
Lloyd's Experiments on Electrically Welded Joints, by H. Jasper Cox.
Industrial Training in War Time, by E. E. McNary.
Training of Electric Welders, by H. A. Hornor.
Electric Arc Welding in Tank Construction, by R. E. Wagner.
An Electrically Welded Freight Car, by J. A. Osborne.
Electric Welding at Erie Works, G. E. Co., by Hermann Lemp and J. R. Brown, Jr.
Spot Welding of Heavy Plates, by W. L. Merrill.
Metallurgy of the Arc Weld, by W. E. Ruder.

Statement of the National Research Council

By GALEN H. CLEVENGER

The Research Committee of the Bureau is also the Research Committee of the National Research Council by votes as follows:—

Vote of AMERICAN BUREAU OF WELDING *July* 11, 1919

"That the National Research Council be invited to accept the Research Committee of the American Bureau of Welding as their Research Committee on Welding and to co-operate with the Bureau in this connection."

Vote of Division of Engineering of National Research Council July 31st, 1919

"That the Research Committee of the AMERICAN BUREAU OF WELDING *be designated as the Welding Research Committee of the Division of Engineering of the National Research Council."*

THE National Research Council is an organization of the Scientific and Engineering forces of the country. It came into being with the war, following the attack upon the "Sussex," in the spring of 1916, when President Wilson requested the National Academy of Sciences to assist in organizing the scientific and engineering forces of the United States for purposes of defence. It will be remembered that the National Academy of Sciences itself was organized during the latter years of the Civil War, with the approval of President Lincoln, to perform a similar service. After careful consideration, it was decided that the desired end could best be attained by creating a new organization which, however, would be most closely affiliated with the Academy and enjoy all of its advantages.

Accordingly, the National Research Council was formed comprising the chiefs of the technical bureaus of the Army and Navy, the heads of the civilian bureaus of the Government engaged in scientific research and engineering, investigators representing the educational institutions, research foundations, and representatives of industrial engineering research.

The Division of Engineering, one of the eight divisions of which this the war organization of the Council was composed did most effective work in many directions throughout the war.

In 1918, President Wilson issued an executive order requesting that the National Research Council be perpetuated. Following this the effecting of the permanent organization of the Council was rapidly accomplished. The Council, as now organized, consists of thirteen divisions; six of these deal with general relations and seven with science and technology. The divisions of science and technology cover the whole field of pure and applied science. One of the most important of this group of divisions is the Division of Engineering.

The National Research Council is in reality a federation of research interests whose purpose it is to promote research in the mathematical, physical and biological sciences and in the application of these sciences to engineering, agriculture, medicine and other useful arts, with the object of increasing knowledge, of strengthening the national defence and of contributing in other ways to the public welfare.

Although the Government contributed to the financial support of the National Research Council during the war period and the Council, in turn, co-operated in the freeest manner with the various Governmental departments and bureaus, it is not a Government organization and is now supported by private endowment.

The Division of Engineering is not a doer of research but rather is a stimulator and co-ordinator of research.

Contributors to this Issue

GERALD W. HINKLEY; author of A Few Secrets of the Metallurgist. Graduated from Cornell in 1916. At the time of his death in 1918 he was assistant to the President of the Atlas Crucible Steel Co., and chairman of the Board of Managers.

RALPH G. HUDSON; professor of Electrical Engineering at the Massachusetts Institute of Technology; author of Engineers' Manual, Manual of Mathematics, Table of Integrals, and Associate Editor of the American Handbook for Electrical Engineers; Consulting Engineer for various industrial companies.

HERMANN LEMP; fellow of the American Institute of Electrical Engineers; born and educated in Switzerland. Former Chief Engineer of the Thomson Electric Welding Company; since 1881 connected with the General Electric Company or its predecessors; at present Works Engineer at the Erie, Pennsylvania, plant. Has been granted more than 200 patents and contributed various papers on Electric Welding.

J. H. DEPPELER; a graduate of Stevens Institute of Technology, with 12 years' experience in welding work. For the last seven years he has been connected with the Metal & Thermit Corp. as Chief Engineer of the Thermit Department.

C. A. ADAMS; professor of Electrical Engineering at Harvard University, now Dean of the new Harvard Engineering School. Past President of the American Institute of Electrical Engineers; Chairman of the Engineering Division of the National Research Council.

H. SIDNEY SMITH; President of International Acetylene Association; Chief Engineer of Prest-O-Lite Company; Past President of British Acetylene and Welding Association.

GALEN H. CLEVENGER; Metallurgist and mining engineer; Vice-Chairman Engineering Division, National Research Council.

M. KEITH DUNHAM; author of Automobile Welding. Engineer for The Bastian Blessing Company.

S. W. MILLER; welding engineer, writer on metallurgical and welding topics, of the Rochester Welding Works.

THE ENGINEERING INDEX

Welding Section

Compiled by The American Society of Mechanical Engineers

IN the preparation of this index the engineering staff of The American Society of Mechanical Engineers regularly examines all of the technical journals and society publications received by the Engineering Societies Library, which form one of the greatest and most complete collections of scientific periodicals in the world, comprising upward of 1100 distinct publications. In all cases where the titles of articles are not sufficiently descriptive, explanatory sentences are appended.

Acetylene Generating Plant

Acetylene Generating Plant for Large Welding Shops. Acetylene & Welding Jl., vol. 16, no. 188, May, 1919, pp. 93-94, 1 fig. It consists of seven generators, gas collector, moisture separator, two condensers, gasometer capable of storing 350 cu. ft. of gas and four large purifiers with bypasses for working in pairs.

Aluminum Welding

The Vertical Welding of Aluminum. Acetylene & Welding Jl., vol. 16, no. 188, May, 1919, pp. 94 & 99, 2 figs. Tests made on sheet aluminum of 11 and 14 gage.

Boiler Repairs

Repairs to Boilers and Engines by Welding, E. G. Hiller. Can. Machy., vol. 21, no. 21, May 22, 1919, pp. 520-521, 2 figs. Examples such as repairing wrought steel, hot-water boiler which was fractured at fire hole and building up by electric welding flanged seams of flue-tube for Lancashire boiler. Paper read before Instn. Mech. Engrs.

Concrete, Reinforced, Construction

Autogenous Welding in Reinforced-Concrete Construction (Die Flammenverschmelzung im Eisenbetonbau). Autogene Metallbearbeitung, vol. 12, no. 1, Jan., 1919, pp. 26, 12 figs. Description of method of construction said to be especially suited for concrete vessels and large tanks. (To be continued).

Cylindrical Bodies

Welding Performed on Cylindrical Bodies, Ernest Schwartz. Can. Machy., vol. 21, no. 22, May 29, 1919, pp. 552-553, 4 figs. Concerning welding of seams and of head and bottom cylindrical bodies.

Dredges

Oxy-Acetylene and Electric Welding on Dredges, H. G. Blankman. Min. & Sci. Press, vol. 118, no. 21, May 24, 1919, p. 716. Also Metal Trades, vol. 10, no. 6, June, 1919, p. 257. Can. Klondyke Mining Co. operates three large dredges and has installed in its machine shop an oxy-acetylene welding equipment. Article quotes results obtained.

Electric Welding

Electric Arc Welding Methods, H. L. Unland. Elec. Ry. Jl., vol. 54, no. 7, Aug. 16, 1919, pp. 343-344, 4 figs. Function and practical operation of various types of equipment for carbon- and metal-electrode welding.

Electric Arc Welding Equipment, H. L. Unland. Metal Trades, vol. 10, no. 8, Aug. 1919, pp. 355-359, 1 fig. Table showing approximate kilowatt-input required for various systems; also classification of different types of welding equipment and discussion of uses of each.

Electric welding: Its Theory, Practice, Application and Economics, H. S. Marquand. Elecn., vol. 83, nos. 2149, 2150 and 2151, July 25, Aug. 1 and 8, 1919, pp. 91-92, 116-118 and 139-141, 29 figs. July 25: Tests to determine strength of electrically welded flanges. Aug. 1: Examples of welding an anchor and locomotive frames. Aug. 8: Example of repairing main drive wheel of Atlantic type locomotive, in which three of spokes gave way by cracking in neighborhood of coupling rod crankpin boss.

Electric Welding and Welding Appliances—XIII. Engineer, vol. 127, no. 3306, May 9, 1919, pp. 444-446, 5 figs. Machines manufactured by A1 Manufacturing Co., of Industry Works, Bradford. They produce machines and accessories for resistance welding only.

Electric Welding in Warships, W. H. Gard. Mar. Engr. & Naval Architect, vol. 41, no. 500, May, 1919, pp. 238-244, 7 figs. Among various examples of repair work, restoring of cast-steel sternpost of battleship is quoted as significant development of process. Paper read before Inst. Naval Architects.

Important Factors for Efficient Arc Welding, E. Wanamaker and H. R. Pennington. Ry. Elec. Engr., vol. 10, no. 6, June, 1919, pp. 179-185, 13 figs. Concerning flexibility of installations, location of accessories and eye and body protection.

Relation of Arc Phenomena to Electric Welding, C. D. Fawcett. University of Colorado, Jl. of Eng., vol. 15, no. 3, Apr. 1919, pp. 15-24, 2 figs. Suggestions in regard to welding practice with table giving approximate relation of electrode diameter, plate thickness, etc.

Electric Arc Welder for Portable and Stationary Use. Automotive Industries, vol. 40, no. 23, June 5, 1919, p. 1233, 2 figs. Outfit designed for operation on either direct current or alternating current lines.

The Plastic-Arc System of Welding, J. O. Smith. Coal Age, vol. 15, no. 26, June 26, 1919, pp. 1162-1166, 7 figs. Also Ry. Rev., vol. 64, no. 24, June 14, 1919, pp. 898-900, 9 figs. Description of outfit and examples of repairs effected by this system. Paper presented before meeting of Coal Min. Elecns. and Mechanics Inst.

Electrodes

Composition of Electrodes. Iron Age, vol. 104, no. 8, Aug. 21, 1919, pp. 503-504, 8 figs. Tests to determine effect of chemical composition of physical characteristics on weld made by Wilson Welder and Metals Co., New York City.

Effects of Chemical Composition of the Electrode on the Welded Material, Decey Welder. Welding Engr., vol. 4, no. 8, Aug. 1919, pp. 42-44, 9 figs. Results of analysis.

Engine Cylinders, Liberty

Welding Operations on Liberty Motor Cylinders, H. A. Carhart. Am. Mach., vol. 50, no. 22, May 29, 1919, pp. 1019-1025, 13 figs. Mixtures and apparatus used by Lincoln Motor Co.

Fusion Welding

Fusion Welding as Applied to Drop-Forging, S. W. Miller. Am. Mech., vol. 51, no. 8, Aug. 21, 1919, pp. 378-382, 29 figs. Consideration given to both electric-arc and oxy-acetylene processes. Physical effects that may occur in weld and in adjoining sections of metal due to heat developed and method of application of processes illustrated with photomicrographs.

Gas Cutting Torches

Modern Welding and Cutting. Am. Mach., vol. 50, no. 23, June 5, 1919, pp. 1081-1087, 15 figs. Difference between gas cutting torches and those used for welding; details of various makes of gas cutting torches. 13th article.

Modern Welding and Cutting—XIV, Ethan Viall. Am. Mach., vol. 50, no. 26, June 26, 1919, pp. 1237-1243, 15 figs. Gas-pressure regulators and working assemblies; directions for lighting of torch; charts showing various flame characteristics with different gas combinations.

Hydraulic-Press Cylinder, Welding of

Welding a Badly Broken Cylinder of a 200-Ton Capacity Hydraulic Press, Nels Johnson. Welding Engr., vol. 4, no. 8, Aug., 1919, pp. 34-36, 2 figs. Work done at Soo Line Railroad shops at Minneapolis, Minn.

Malleable-Iron Welding

Some Considerations Affecting the Welding of Malleable Iron, H. A. Schwartz. Welding Engr., vol. 4, no. 8, Aug., 1919, pp. 21-23, 9 figs. Photomicrographs illustrating various kinds of welds.

Oxy-Acetylene Welding

Filling Cavities and Putting on Parts by the Oxy-Acetylene Process, J. F. Springer. Ry. & Locomotive Eng., vol. 32, no. 8, Aug., 1919, pp. 233-234. Cases in which cavities in castings may be filled and thus save expense of recasting.

Oxy-Acetylene Welding Investigation, J. H. Davies. Can. Manufacturer, vol. 39, no. 8, 16, 1919, pp. 317-319, 8 figs. Construction of for securing good results; also results of carbon-steel experiments. Paper read before Inst. Mech. Engrs.

Building Special Work with an Oxygen-Acetylene Cutting and Welding Outfit, Montelle C. Smith. Elec. Ry. Jl., vol. 54, no. 7, Aug. 16, 1919, pp. 317-319 8 figs. Construction of frogs, switches, switchmates, and similar work jobs.

Acetylene Welding. Ry. Jl., vol. 25, no. 6, June, 1919, pp. 18-19. Committee report before Master Boiler Makers' Assn.

Great Britain's Acetylene Welding Industry—its Birth, Growth and War Record, Norman MacLeod. Jl. Acetylene Welding, vol. 2, no. 12, June, 1919, pp. 601-606, 8 figs. Founding of Northern Polytechnic Inst., and featuring courses in autogenous welding. Among samples of welding applications, the reconstruction of a bomb dropped in London by a German zeppelin is described.

Shutdown of Great Steel Plant Avoided by Oxwelding, L. M. Malcher. Jl. Acetylene Welding, vol. 2, no. 12, June, 1919, pp. 611-614, 5 figs. Repairing wrecked low-pressure cylinder which was cracked at head end in seven different places.

A Difficult Cylinder Bloc Job, David Baxter. Jl. Acetylene Welding, vol. 2, no. 12, June, 1919, pp. 607-610 & 622, 10 figs. Presented as case in which welding operator was handicapped by intense heat radiating against tip at close quarters from every direction and very limited space in which to manipulate.

Notable Repairs on Large Cylinder by Oxy-Acetylene Welding, L. M. Malcher. Pac. Mar. Rev., vol. 16, no. 6, June, 1919, pp. 104-105, 4 figs. Cylinder of Allis-Chalmers twin compound reversing engine, 70 in. diameter, badly fractured. Cost of repair estimated about one-third of that of a new cylinder.

Welding by the Oxy-Acetylene Method—III, J. F. Springer, Automobile Eng., vol. 4, no. 5, May, 1919, pp. 238-239, 2 figs. Examples of successful welds in cast-iron frames, with remarks on methods of making welding groove and filling it with new metal.

Thermit Welding

Thermit Process Used on Big Welding Job on Northern Pacific. Mar. News, vol. 6, no. 2, July, 1919, pp. 96-97, 5 figs. Illustrating repair on cast-steel stern frame which was cracked through just above upper post gudgeon, the break forming roughly a triangle, each side of which was about 2 ft. long.

Restoring Steel Machinery to Service by the Thermit Process. Welding Engr., vol. 4, no. 6, June, 1919, pp. 29 and 32-33, 14 figs. Examples of repairs of large pieces of work for Pittsburgh Steel Co.

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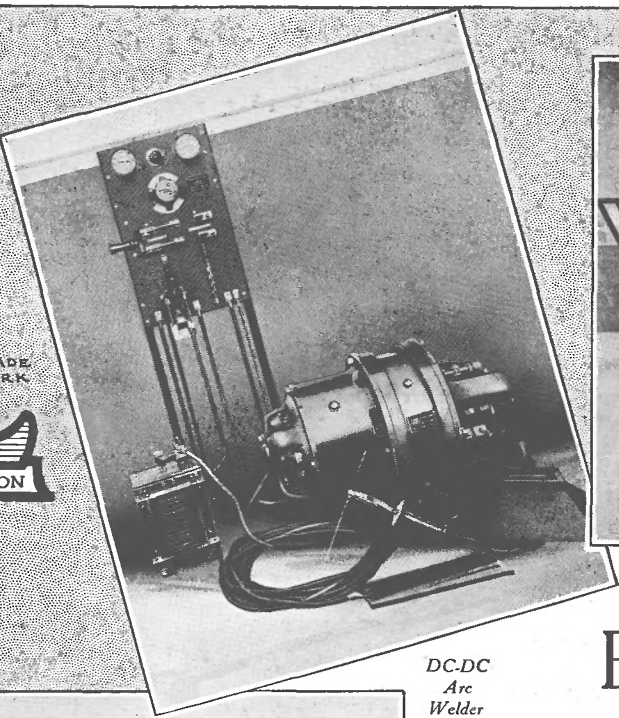

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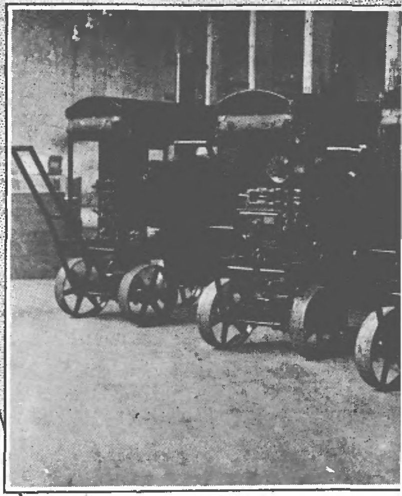

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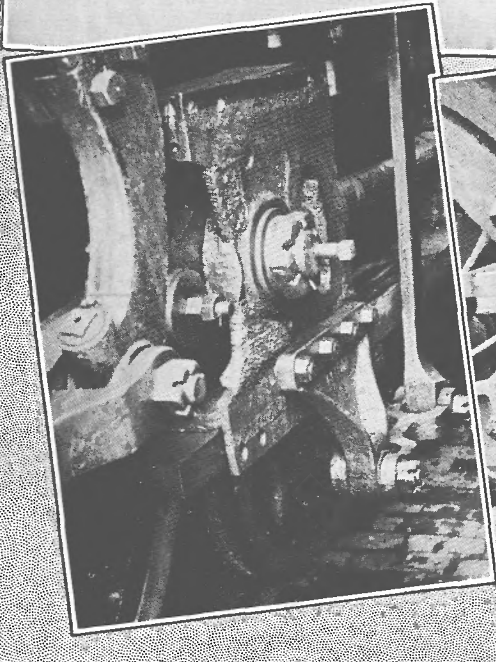

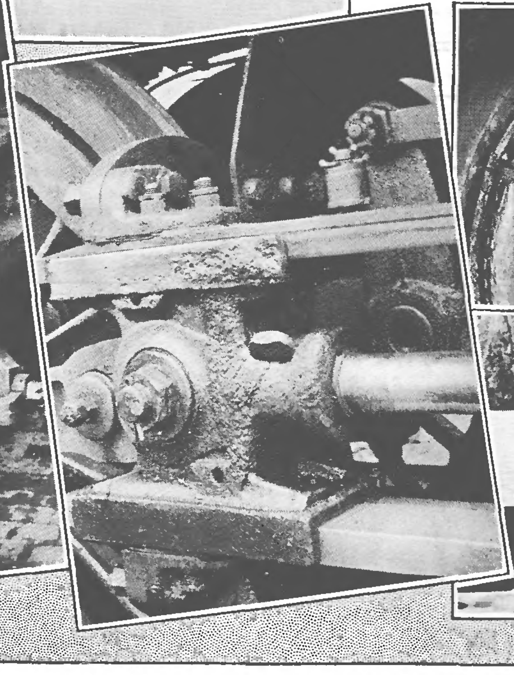

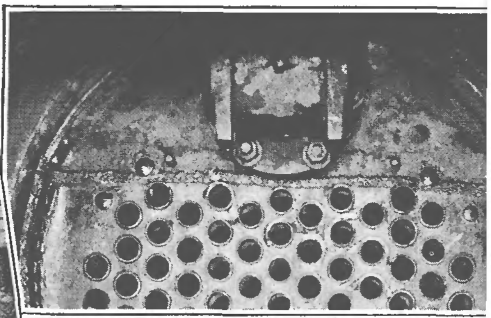

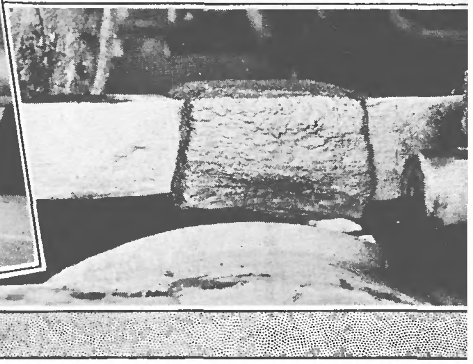

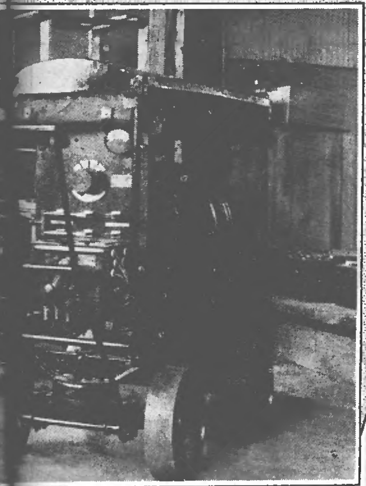

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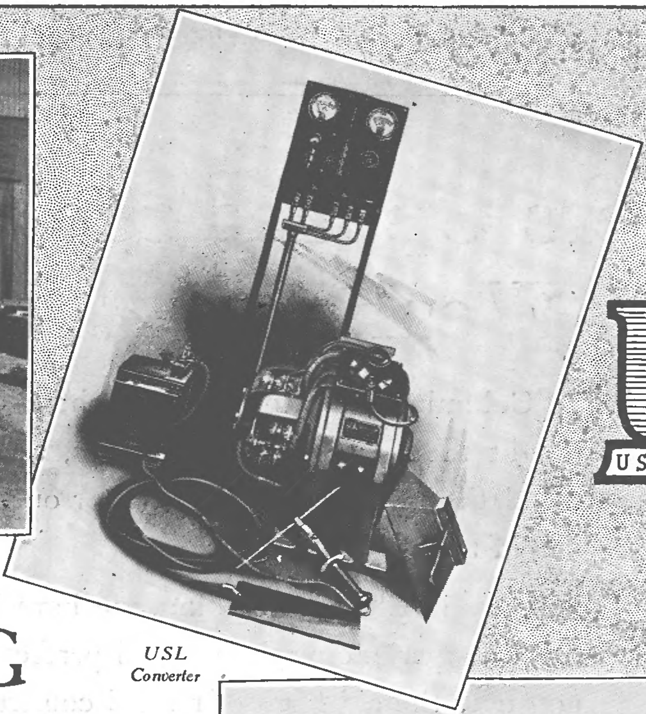

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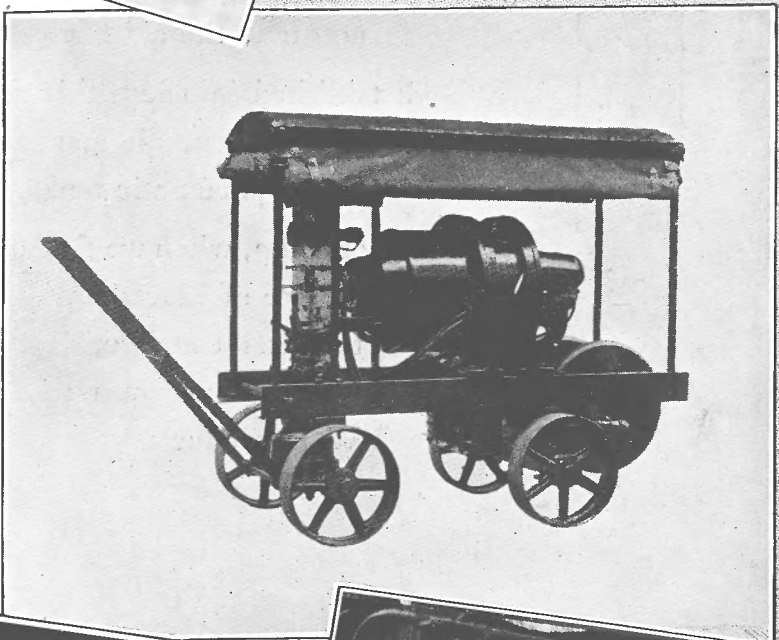

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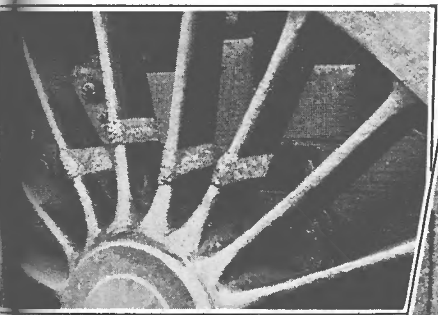

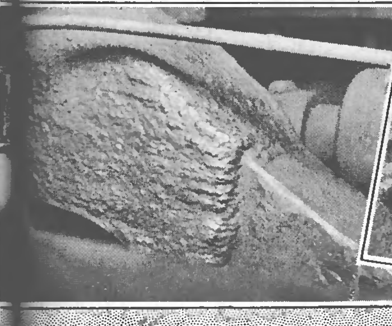

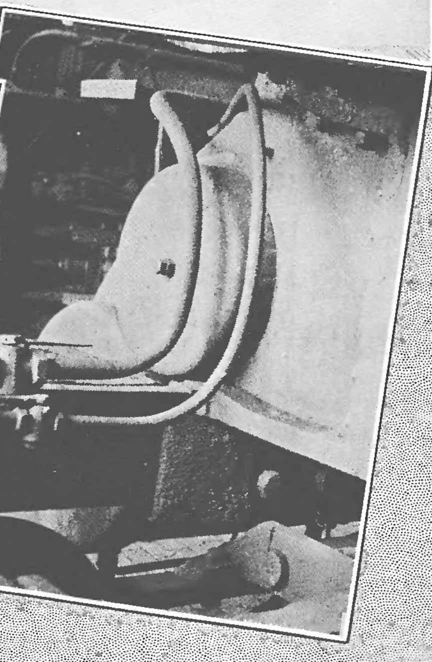

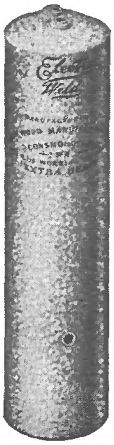
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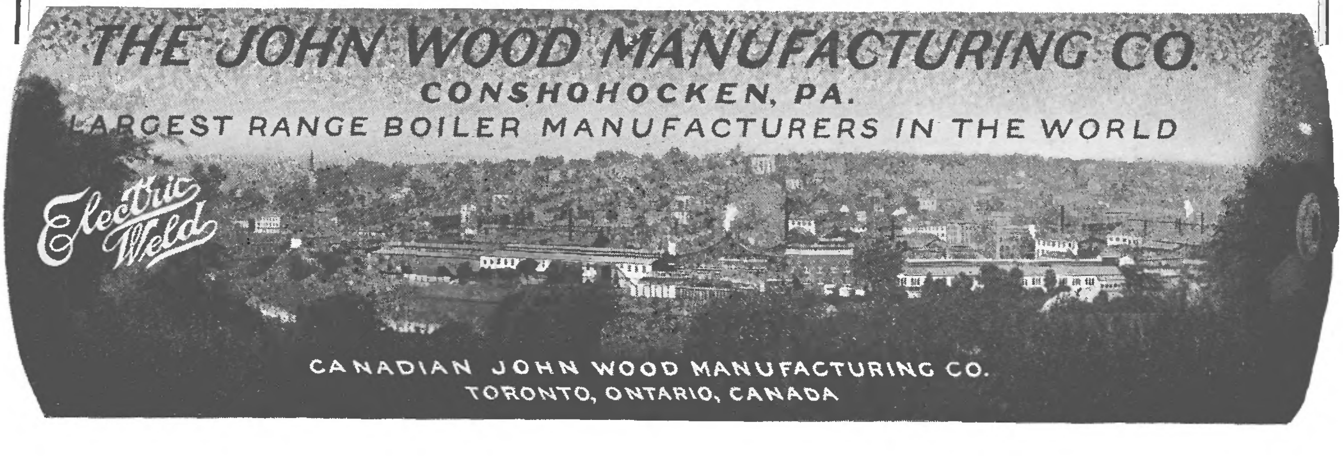

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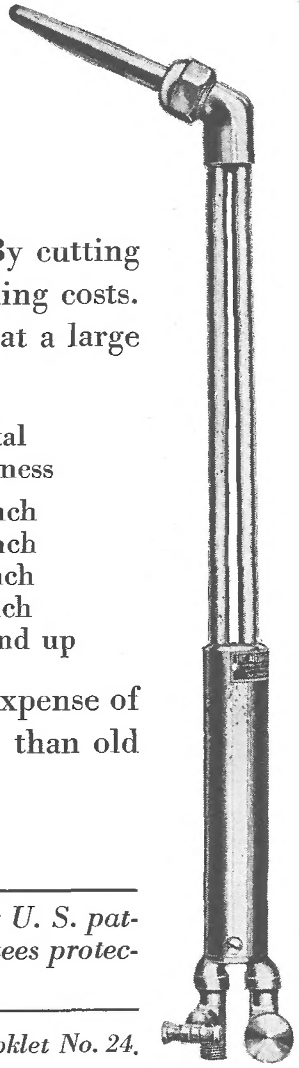

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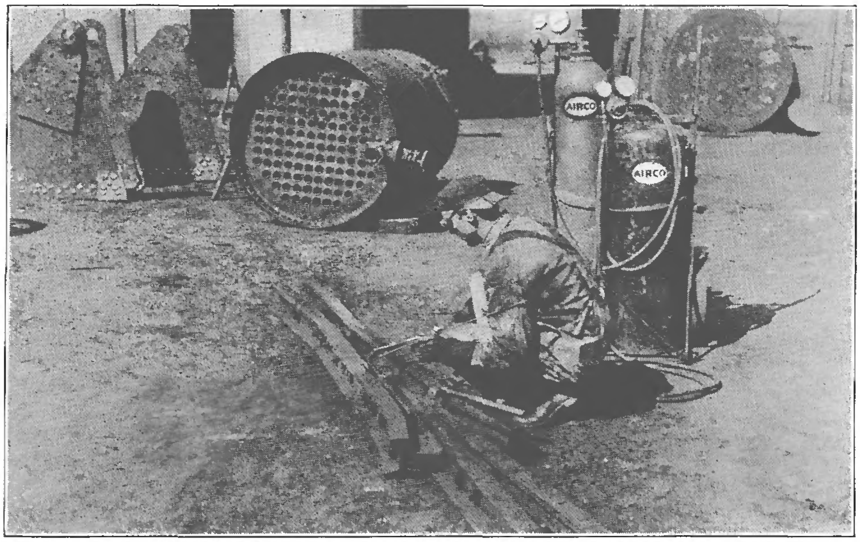

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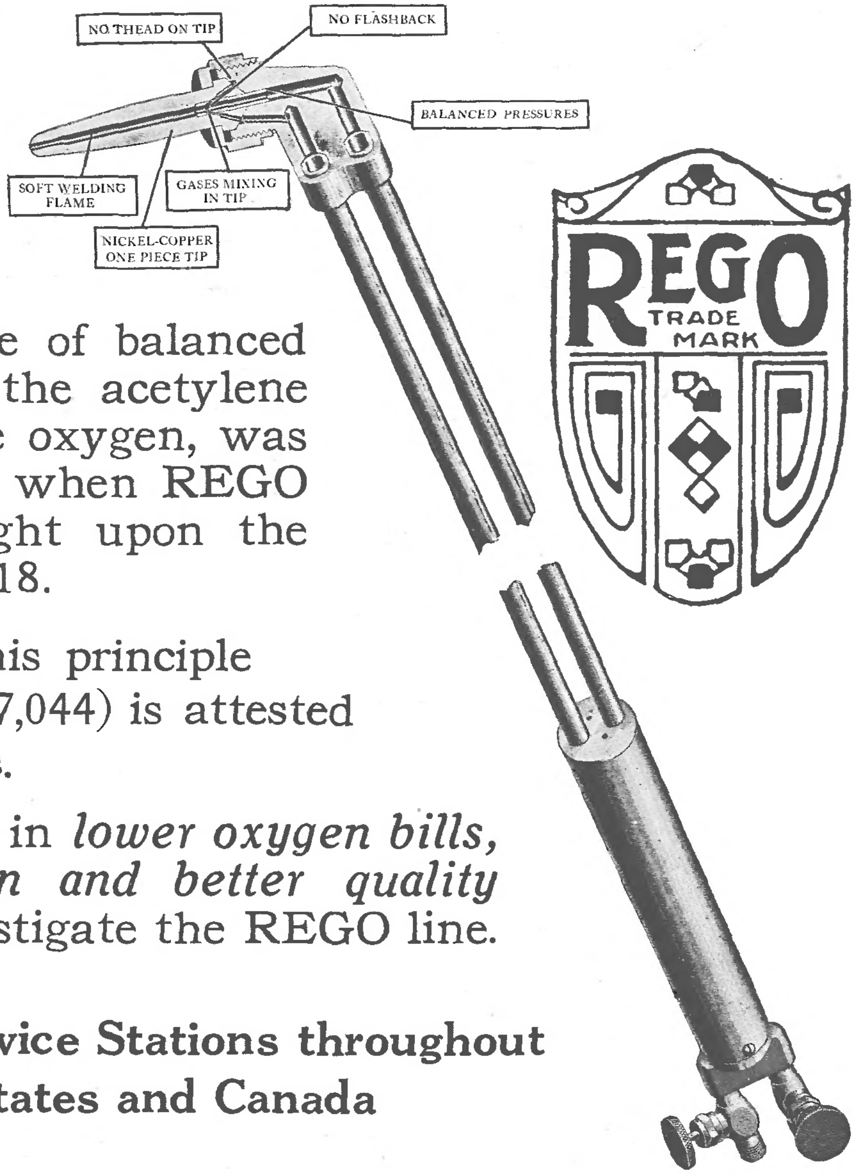
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20% More Work Per Day

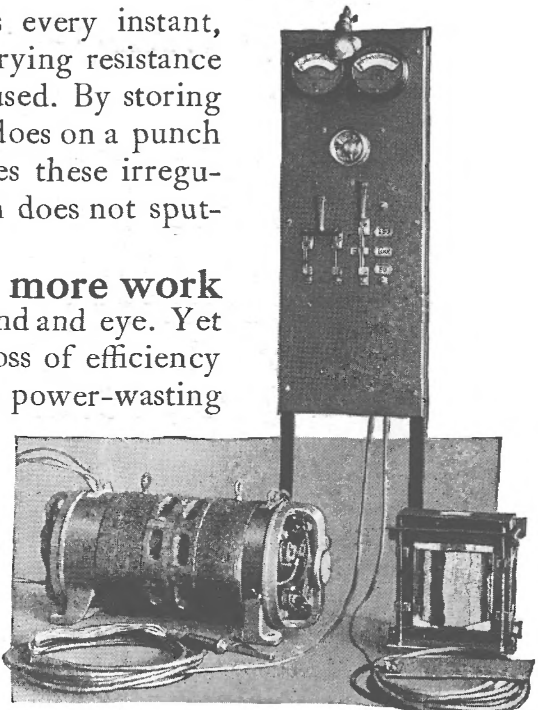
The steady arc assured by the stabilizer feature of the Lincoln Arc Welder means more work per day.

The resistance of a welding arc varies every instant, because of the uneven surface and the varying resistance of the work upon which it is being used. By storing up reserve power—just like a flywheel does on a punch press—the Lincoln stabilizer overcomes these irregularities and maintains a steady arc which does not sputter or break.

That is why the operator can do **20% more work** per day—and does it with less strain on hand and eye. Yet the stabilizer does all this without any loss of efficiency to the welding machine. There are no power-wasting resistances—no complicated clapper switches to get out of order—nothing in the whole Lincoln outfit which is not simple, ruggedly constructed and easily and economically operated.

Write for Bulletin 104-A.

"LINK UP WITH LINCOLN"



Motor Generator Control Stabilizer Board

THE LINCOLN ELECTRIC CO.

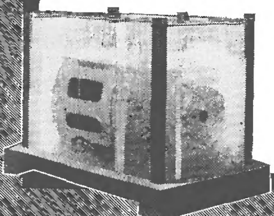
General Offices and Factory, Cleveland, O.

New York City
Buffalo
Syracuse
Baltimore
Cincinnati
Chicago
Detroit
San Francisco
Columbus
Pittsburgh
Philadelphia
Boston
Charlotte, N. C.
Minneapolis

The Lincoln Electric Co., of Canada, Ltd., Toronto, Montreal

Agencies in other Principal Cities

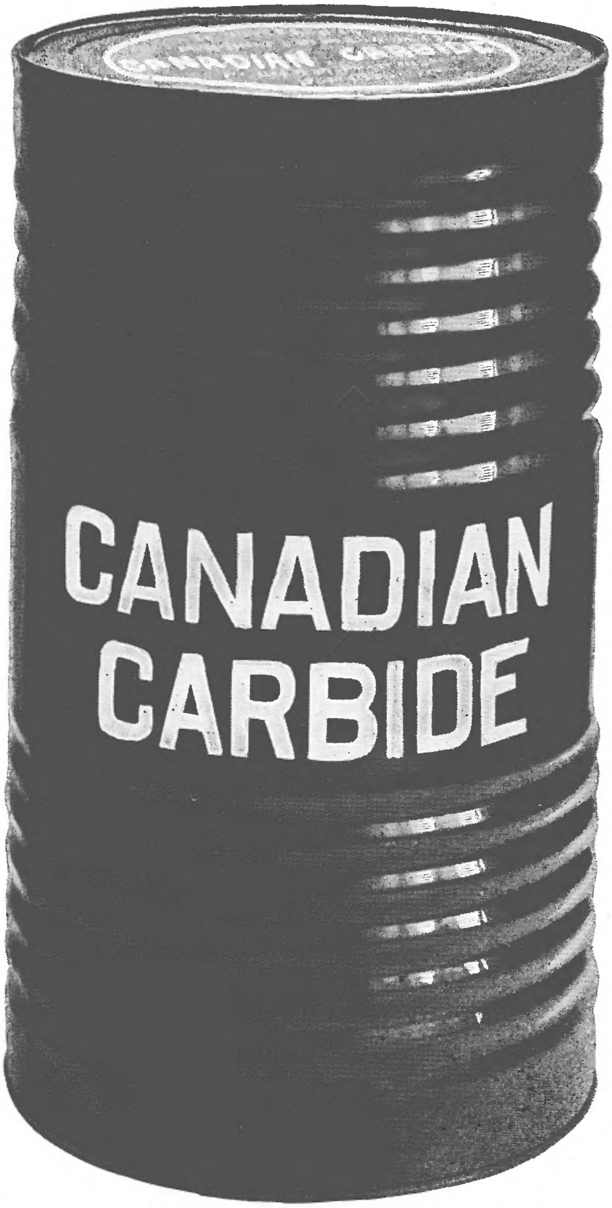
This Lincoln Motor operated under water over 3 years without damage.



Canada Carbide Sales Company Inc.

Main Office
30 Church Street, New York City

Branch Office
549 McCormick Building, Chicago, Ill.



THE GREEN DRUM

Size Packages–1000 lb; 100 lb. & 25 lb. Drum
Size Carbide--3½ x 2 medium
2 x ½ Small
1¼ x ⅜ Nut
¼ x 1/12 Pea

CANADIAN CARBIDE

"More Gas Per Pound"

Distributing Points

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Bessemer, 2014-2024 Second Ave.
ILLINOIS
Belleville; Benton
Chicago, 549 McCormick Bldg.
Christopher
Springfield, 812-814 E. Adams St.
West Franklort
INDIANA
Clinton
Rochester
Terre Haute, 15 N. Eighth St.
IOWA
Albia
Centerville
Knoxville
KENTUCKY
Beaver Creek
LOUISIANA
New Orleans
MARYLAND
Baltimore, 115 E. Lombard St.
Emitsburg
Westernport
MASSACHUSETTS
Boston, 47 Oliver St.
MICHIGAN
Detroit, 343 Bellevue Av.
Grand Rapids, 757 Hawthorne St.
Saginaw, Thompson and Franklin Streets
MINNESOTA
Duluth, 3d Av. East and Michigan St.
Minneapolis 100-112 Second Av. N.
MISSOURI
Joplin, opposite Postoffice
Lexington
NEW JERSEY
Paterson, 61-63 Washington St.
NEW YORK
Buffalo, Seneca & Hamburg Sts.
Cortland, 41 Elm St.
Malone, 32-34 W. Main St.
Middletown, 28 W. Main St.
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Springville
Trumansburg, 55 Main St.
Valley Stream
OHIO
Barton
Canton, 1372 Dueber Av.
Cleveland, 3300 Lakeside Av.
Crescent
Maynard
Nelsonville
Salem
Toledo, 928 George St.
Warren
Wellston
Zanesville, Third & Market Sts.
OKLAHOMA
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Tulsa
PENNSYLVANIA
Altoona, 947 Nineteenth St.
Avonmore
Barnesboro
Clymer
Hastings
Latrobe
Nanty Glo.
Pittsburgh
1222 Farmers Bank Bldg.
40th St. and A. V. R. R.
Portage
Pottsville, Centre & Market Sts.
Saltsburg
Scranton, 339 Penn Ave.
South Fork
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Wilpen
RHODE ISLAND
Providence, 546 Charles St.
TENNESSEE
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TEXAS
El Paso, 323 S. Santa Fe St.
Fort Worth, 415 Throckmorten St.
UTAH
Salt Lake City, 121 W. 2d South St.
VERMONT
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Richmond
WEST VIRGINIA
Charleston, 821 Virginia St.
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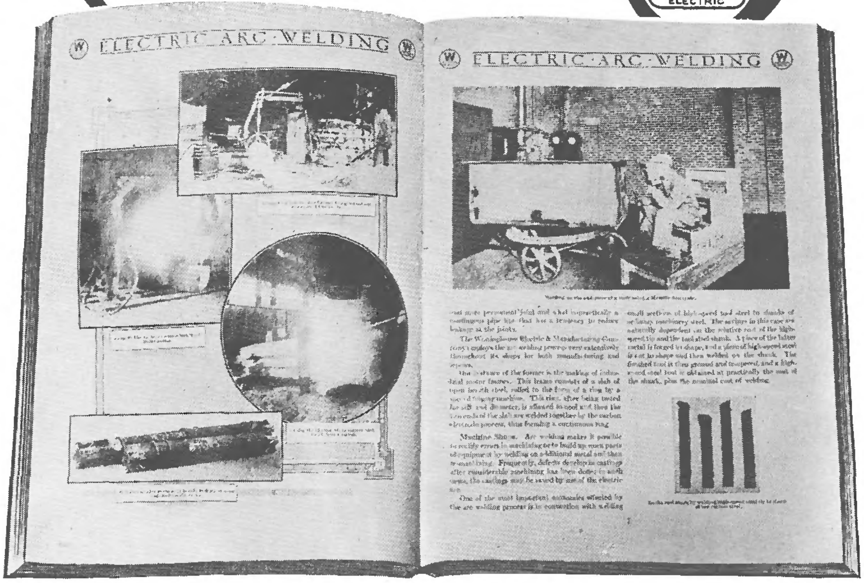
Northfork


ELECTRIC · ARC · WELDING
ELECTRIC · ARC · WELDING

The Oxy-Welding Gauge of To-Day

Accuracy is absolutely essential. With it must go sturdiness, long service and safety. Our SOL-FRUNT Oxy-Welding Gauge — the only gauge with a cast solid front—embodies all these features.

That's why approximately 90% of the trade insist upon it.

Full details and Catalog W. A. gladly sent on request.

U.S. GAUGE CO. N.Y.
Trade Mark

UNITED STATES GAUGE CO.
67 WALL ST. NEW YORK

BOSTON CHICAGO DETROIT NEW ORLEANS PHILADELPHIA SAN FRANCISCO MONTREAL
Distributing Agents Throughout the World

GENUINE SWEDISH IRON
Best Swedish Brands—All Sizes and Sections—Prompt Shipment from American Stocks
GENUINE SWEDISH WELDING WIRE
All Sizes Prompt Shipments from American Stocks Send Specifications

FEDERAL TOOL & ALLOY STEEL CORPORATION
THOMAS TOWNE, First Vice-President and General Manager
Successors to Swedish Iron & Steel Corporation
General Offices - - - - - WOOLWORTH BLDG., NEW YORK CITY
Branch Offices and Warehouses BROOKLYN CHICAGO NEW ORLEANS CLEVELAND

Butt Welders — Spot Welders — Electric Riveters
We design and build Electric Welding and Riveting equipment for any and all purposes

THE WINFIELD ELECTRIC WELDING MACHINE COMPANY
WARREN, OHIO, U. S. A.

NEW YORK CHICAGO CLEVELAND DETROIT BOSTON MONTREAL LONDON PARIS

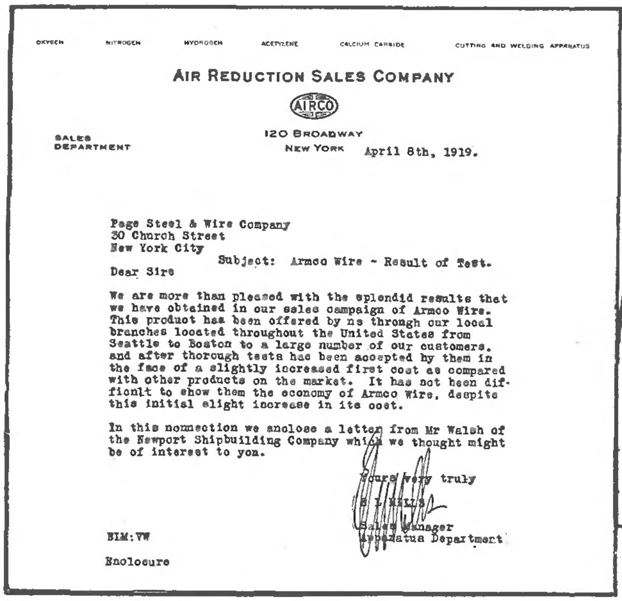
ARMCO IRON WELDING RODS

cost somewhat more than ordinary welding material, but, compared with the total cost of the weld, the difference is insignificant. The difference in the weld, on the other hand, is of vital importance.

AMERICAN ARMCO INGOT IRON

The trade mark ARMCO carries the assurance that iron bearing that mark is manufactured by the American Rolling Mill Company with the skill, intelligence and fidelity associated with its products, and hence can be depended upon to possess in the highest degree the merit claimed for it.

"It has not been difficult to show them the economy of Armco Iron Wire—"



OXYGEN NITROGEN HYDROGEN ACETYLENE CALCIUM CARBIDE CUTTING AND WELDING APPARATUS

AIR REDUCTION SALES COMPANY

AIRCO

SALES DEPARTMENT

120 BROADWAY
NEW YORK April 8th, 1919.

Page Steel & Wire Company
30 Church Street
New York City

Subject: Armco Wire - Result of Test.

Dear Sirs

We are more than pleased with the splendid results that we have obtained in our sales campaign of Armco Wire. This product has been offered by us through our local branches located throughout the United States from Seattle to Boston to a large number of our customers. and after thorough tests has been accepted by them in the face of a slightly increased first cost as compared with other products on the market. It has not been difficult to show them the economy of Armco Wire, despite this initial slight increase in its cost.

In this connection we enclose a letter from Mr Walsh of the Newport Shipbuilding Company which we thought might be of interest to you.

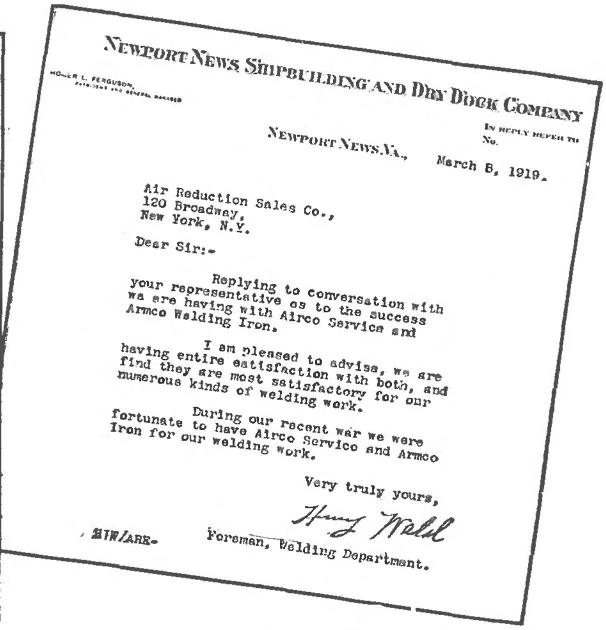
Yours very truly

B L MILLS

Sales Manager
Apparatus Department

BIM:VW

Enclosure



NEWPORT NEWS SHIPBUILDING AND DRY DOCK COMPANY

HOMER L. FERGUSON, PRESIDENT AND GENERAL MANAGER

IN REPLY REFER TO No.

NEWPORT NEWS, VA., March 8, 1919.

Air Reduction Sales Co.,
120 Broadway,
New York, N.Y.

Dear Sir:-

Replying to conversation with your representative as to the success we are having with Airco Service and Armco Welding Iron.

I am pleased to advise, we are having entire satisfaction with both, and find they are most satisfactory for our numerous kinds of welding work.

During our recent war we were fortunate to have Airco Service and Armco Iron for our welding work.

Very truly yours,

Harry J Walsh

HJW/ARE- Foreman, Welding Department.

The above typical letter to one of our distributors shows that the superiority and real economy of ARMCO welding material are readily appreciated. Welders who use ARMCO IRON exclusively have a big advantage over competitors who buy inferior material and their customers soon learn the difference. Another ARMCO IRON advantage from the welder's standpoint is the fact that two kinds of rods of guaranteed ARMCO analysis, one for electric welding and the other for oxy-acetylene welding, do all the work (with better results) that formerly was thought to require a choice of one from many compositions. This means that with a much smaller investment for stock of welding material a shop is fully prepared to handle the usual run of steel and iron welding work.

Because of their exceptional purity and even density ARMCO IRON Welding Rods flow freely, weld evenly, and give a joint that lends itself perfectly to finishing operations.

PAGE STEEL & WIRE CO.

Established 1883 as Page Woven Wire Fence Co.

STEEL AND WIRE PAGE QUALITY PRODUCTS

Makers of ARMCO IRON Welding Rods and Electrical Wire; "Copperweld" Copper Clad Steel Wire; Wire Mill Products, Plain and Galvanized; Wire of Special Analysis; Wire Fencing for all Purposes; Factory Gates; Ornamental Iron Fence; Machine Guards; Tool and Stockroom Partitions; Architectural Iron.

Plants: Monessen, Pa. and Adrian, Mich.

Sales Offices: 30 Church Street, New York

CHICAGO: 29 South La Salle Street, DETROIT: Book Building, SAN FRANCISCO: American Rolling Mill Company of California

CANADIAN DISTRIBUTORS:
Taylor & Arnold, Ltd., Montreal, Toronto, Winnipeg

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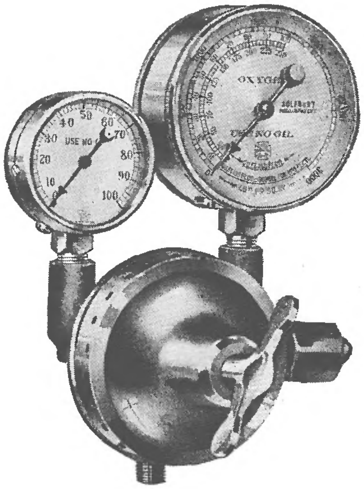

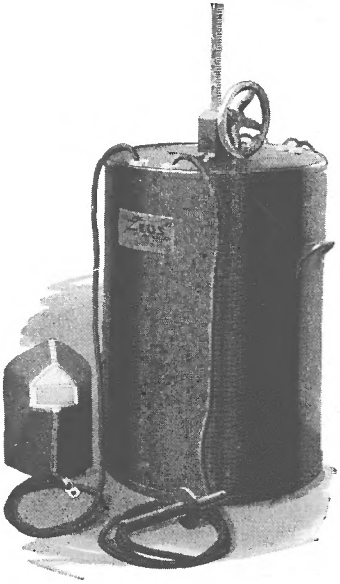


ICC A2015
K334603
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LINDE
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OXY ACETYLENE WELDING
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PIONEER MACHINE SHOP
ALASKA

Doelcam Oxy-Acetylene Welding and Cutting Outfits

Do You Have Trouble Obtaining Oxygen Gas?

If so here is an outfit that will generate both gases.

Size C 2, 25 lb. Acetylene Generator, 1 Welding Torch, Regulators, Hose, Oxygen Generator, capacity 300 cubic feet per day and other Sundries.

Size C 3, 50 lb. Acetylene Generator, Oxygen Generator, capacity 400 ft. per day, 2 Torches, Regulators and other Sundries.

Size C 4, 100 lb. Acetylene Generator, Oxygen Generator, capacity 800 ft. per day, 3 Torches, Regulators and other Sundries.

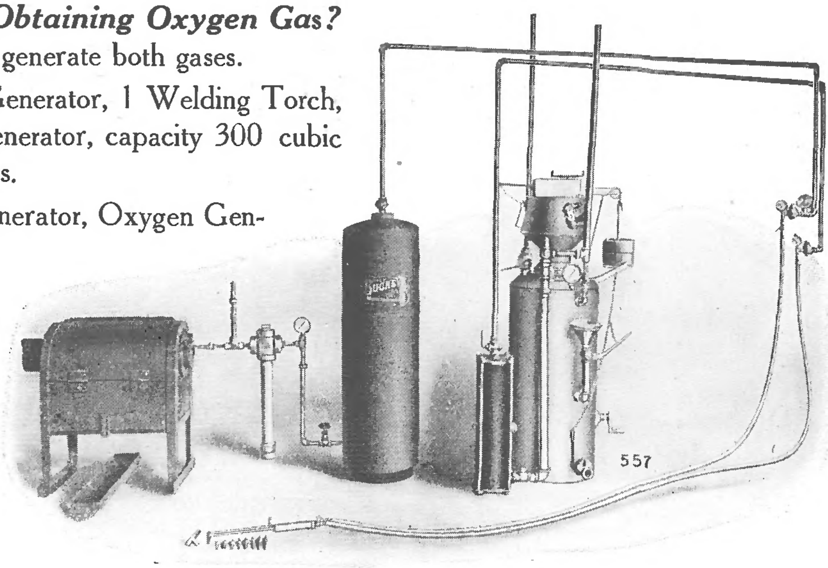


Illustration of Size C 2

Just the plant for export and isolated places such as mines and factories where shipping facilities are not good.

WE BUILD EVERY DESCRIPTION OF OXY-ACETYLENE WELDING AND CUTTING OUTFITS, PORTABLE AND FIXED

588

WE BUILD ACETYLENE GENERATORS UP TO 500 LBS. CAPACITY

DOELCAM PREHEATING TORCHES

USING KEROSENE OIL AS FUEL

SAVE ONE HALF YOUR GAS BY PREHEATING YOUR WORK

Type A.—Portable Independent Outfit

Size No.	25 A	25 C	26 A	27 A
Size Tank Gals.	5	5	10	17
Size Flame	2 x 12	3½ x 15	3½ x 15	6 x 20
Price	40.00	50.00	65.00	96.00

Type A Burner requires preheating before operating.

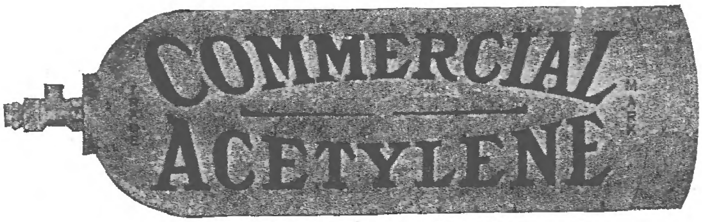
Type B.—Compressed Air Pattern

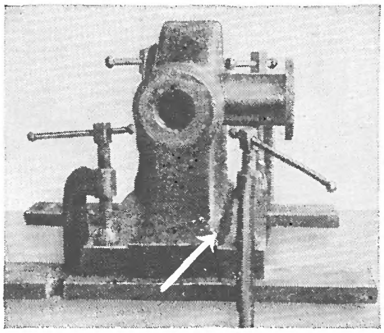
Size No.	11 B	11 C	12 B	13 B
Size Tank Gals.	5	5	10	17
Size Flame	2½ x 14	3½ x 20	3½ x 20	6 x 24
Price	60.00	70.00	80.00	100.00

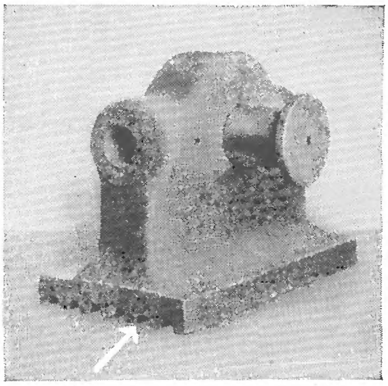
☞ *Always order Type B if you have compressed air available, as the Burner can be started instantly.*

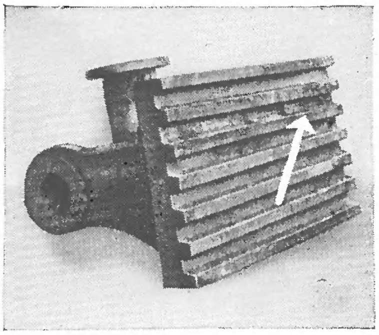
THE MACLEOD COMPANY

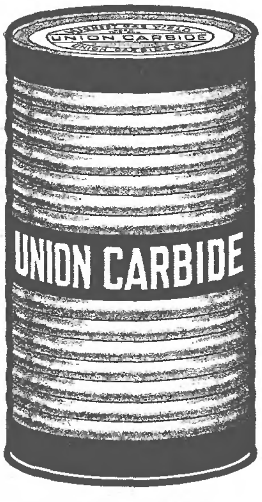
2030 BOGEN STREET - - CINCINNATI, OHIO

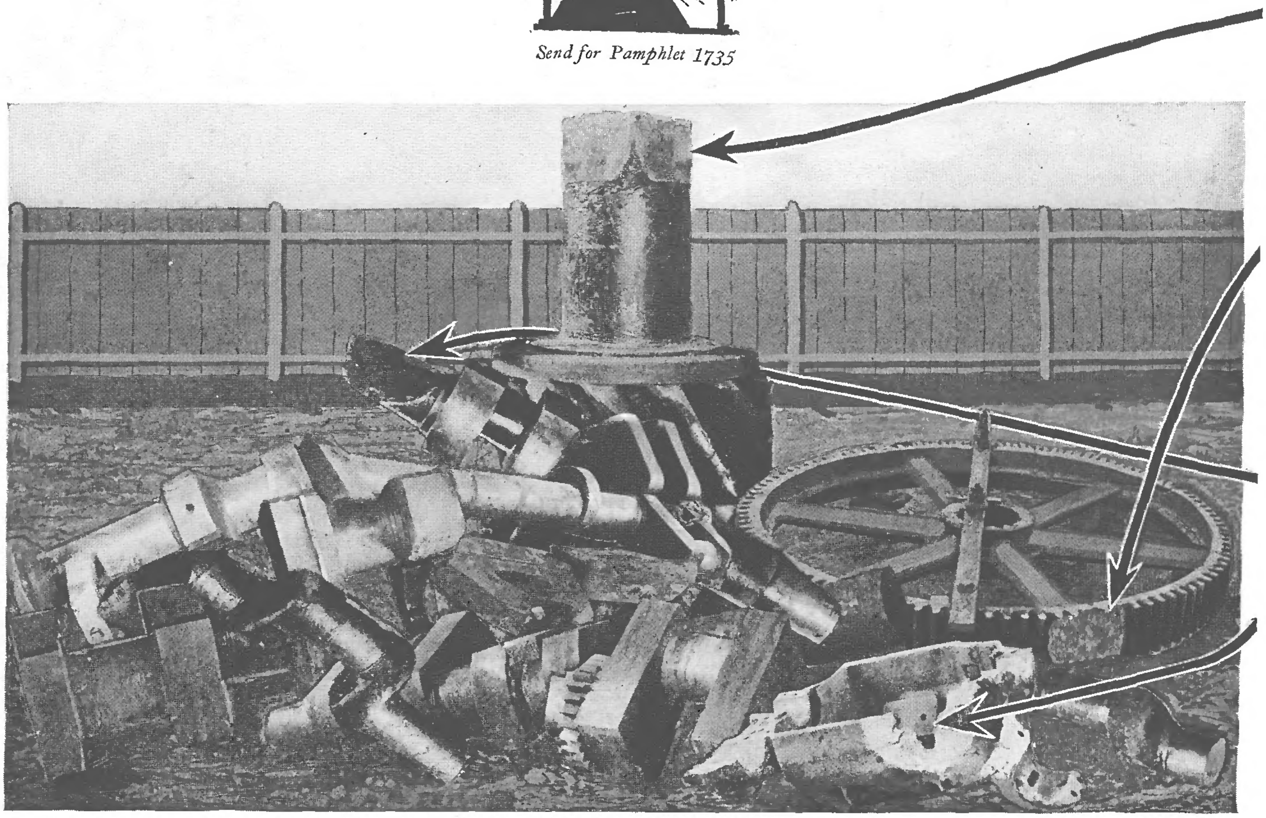

COMMERCIAL
ACETYLENE



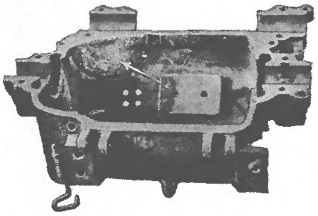


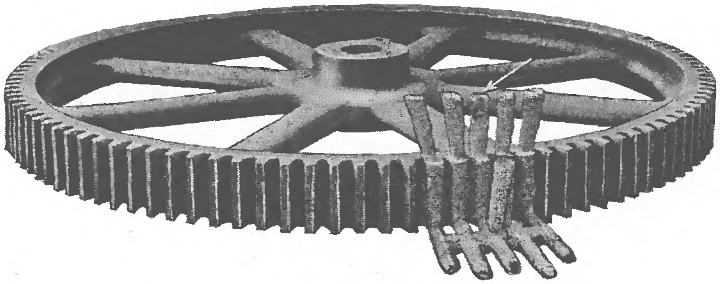


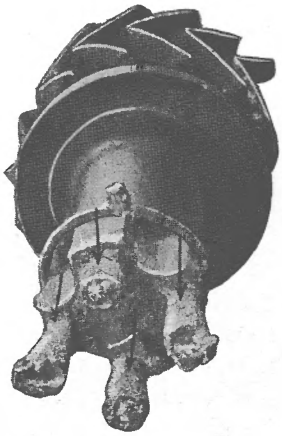

UNION CARBIDE
UNION CARBIDE



equipment lie idle in the scrap heap

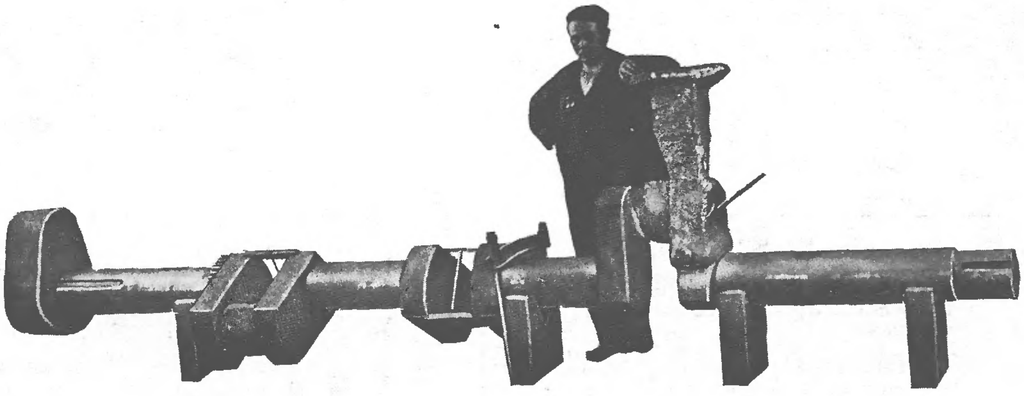






329-333 Folsom Street, San Francisco.
7300 So. Chicago Avenue, Chicago, Ill.
15 Emily Street, Toronto, Canada
1427-1429 Western Ave., Pittsburgh, Pa.

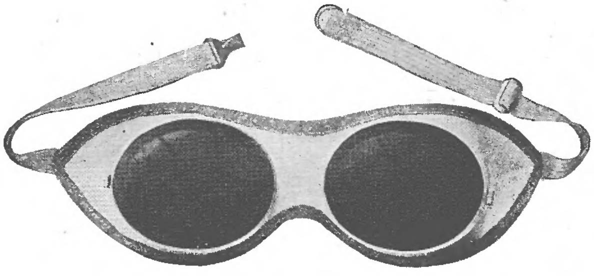
Factories located at Chrome, N. J., Wyandotte, Mich.
East Chicago, Ind., Jersey City, N J.

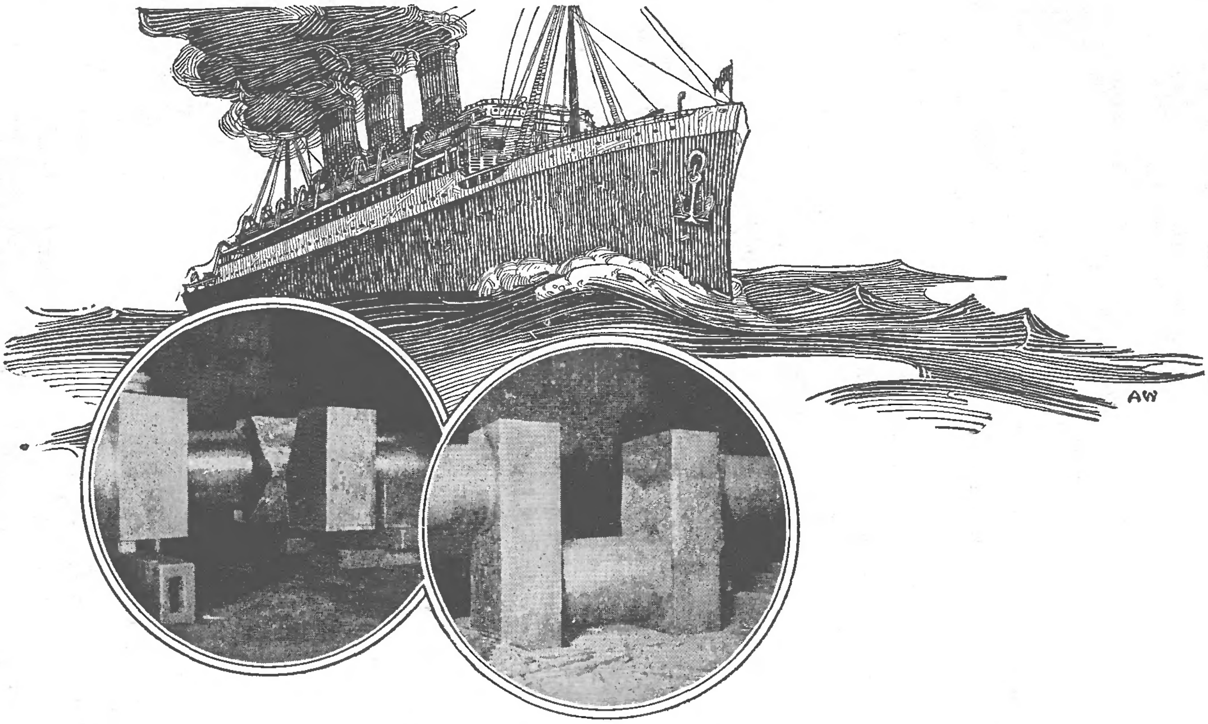


120 BROADWAY, NEW YORK

THERMIT


SYSTEM
I.O.C.
BR

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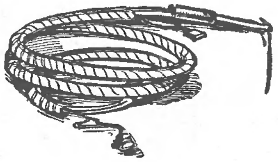

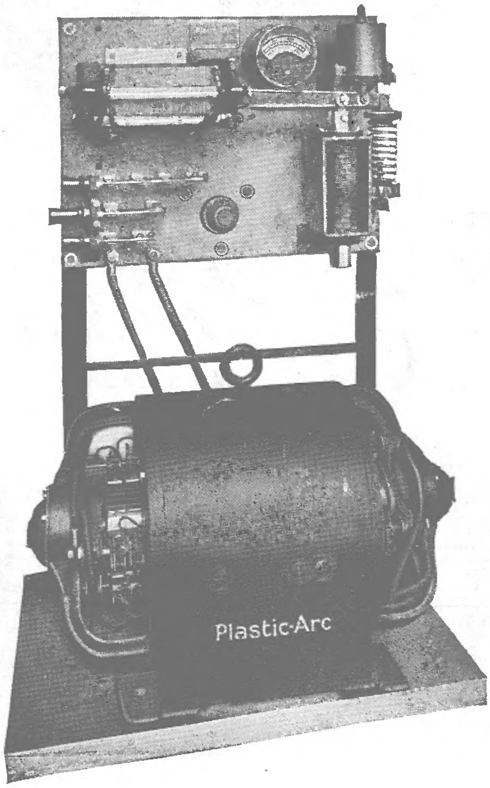
Plastic-Arc