MODERN METHODS OF WELDING.

THE union of two pieces of metal by fire fusion and hammering is an old-established art in connection with iron, and is rendered easy by the fact that the change from liquid to solid is not abrupt in the case of this metal, which exists in a pasty condition over a considerable range of temperature. Since the invention of the oxy-hydrogen blowpipe by Hare in 1801, steady progress has been made with the welding of iron and other metals by methods involving flame heating, the earliest successes in this direction being achieved with platinum and lead. During the last ten years flame welding has made rapid strides, mainly owing to the use of acetylene as the combustible gas, and is now firmly established as an everyday process in all large engineering workshops. The high temperature procurable by the use of electricity has led to the development of electric welding, which is now employed for a large variety of operations, and may be expected to extend still more as electric power grows cheaper. In addition to the foregoing, a further method of welding is provided by the use of "thermit" mixture, which has proved successful for many classes of work. During the present time of stress all the methods named are being used to the utmost, and are playing an invaluable part in the production of munitions of war.

The gases used for flame welding may be either hydrogen, coal-gas, water-gas, or acetylene, which are burnt in blowpipes of suitable construction in air or oxygen, according to the temperature needed. Hydrogen is more expensive than the other gases named, and is used only in cases in which the work might be damaged by impurities such as sulphur and phosphorus, one or both of these being liable to be present in the alternative gases. Coal-gas has long been used for the autogenous soldering of lead, but has not been applied to any great extent to the welding of iron, owing to its varying composition and the presence of impurities. Water-gas, which has the advantage of being the cheapest of all gases suitable for welding, is now extensively employed for pipe welding, particularly in America and Germany, the parts to be joined being brought to a welding heat by blowpipes, and then hammered with a pneumatic hammer, or pressed together by rollers. Fig. 1, from a paper published by Capt. Caldwell, R.E., in the Transactions of the Institution of Engineers and Shipbuilders in Scotland for February last, shows a pipe welded in this manner and used in a hydro-electric installation in California. Water-gas is used in this connection as a substitute for a fire, and the temperature attained need not be so high as that required for fusion welding, in which joining is effected without hammering.

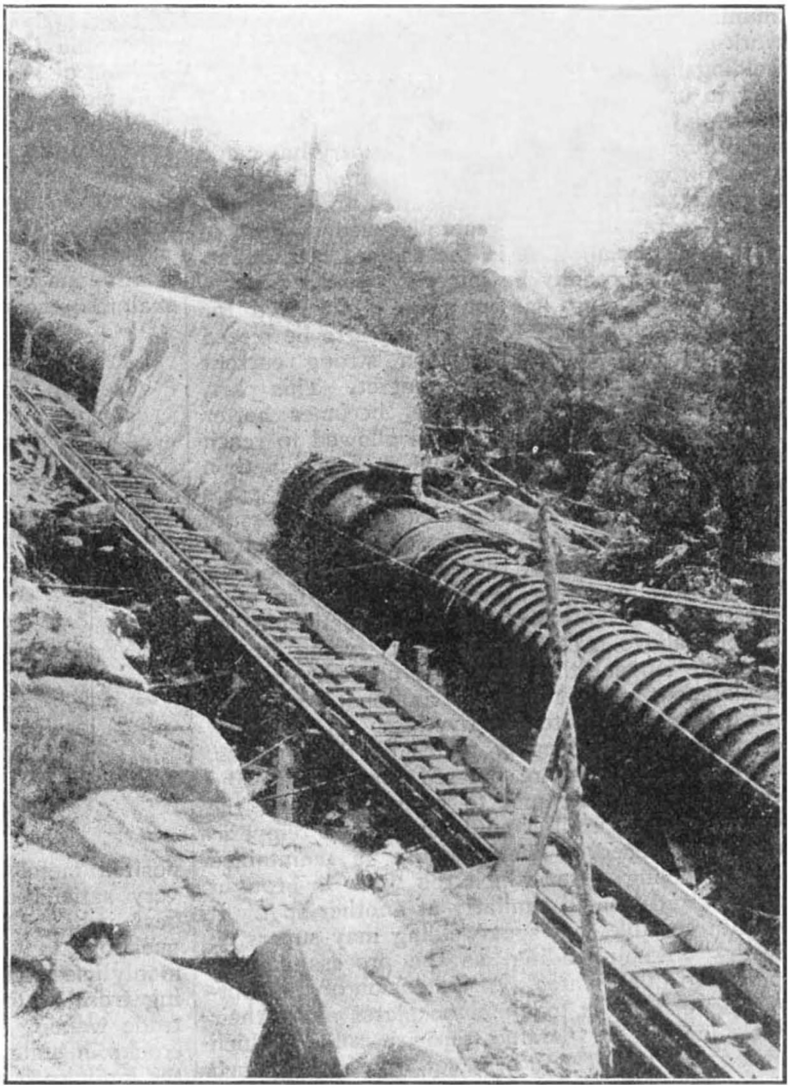

FIG. 1.—Large pipe welded by water-gas method. From Transactions of the Institution of Engineers and Shipbuilders in Scotland.

The oxy-acetylene flame is most generally used for fusion welding, owing to its high temperature, which, at the hottest part, approaches 3000° C., a further advantage being that a zone of unburnt hydrogen exists round the working-tip of the flame, which prevents oxidation of the work. In fastening two surfaces by fusion welding, the edges are chamfered and brought together so as to form a V-groove. The lowest part of the groove is brought to fusion by the blowpipe, and metal run in from a rod held in the flame, the process being continued until the groove is filled, when, if both the work and added metal have been thoroughly fused, a good joint will result. The oxy-acetylene flame is extensively used in this manner for welding iron, and is now growing in favour for joining non-ferrous metals, such as aluminium, copper, brass, and bronze. The framework of a Zeppelin is a notable example of fusion welding in aluminium, for which metal it is necessary to use a suitable flux. Largely owing to the work of Capt. D. Richardson, R.F.C., the welding of non-ferrous metals in this country has made great progress within recent years, the oxy-acetylene flame, and a flux suited to the metal under treatment, being generally used. The process is of special value in the case of aluminium, which cannot readily be joined by soldering.

Electric welding has long been employed for joining iron and steel rods, the ends to be pieced being brought together, and a strong current passed through the point of contact. This part, owing to its higher resistance, becomes hotter than the rest of the rod, and is allowed to reach the fusion point. Longitudinal pressure is then applied, so that complete union of the two parts may be ensured; and after releasing the pressure the weld is hammered during cooling. An alternating current is used, the requisite high current at low voltage being secured by the use of a transformer. This method is impracticable for sections above a certain diameter, owing to the excessive current that would be needed. A later development is what is known as "spot" welding, which is a substitute for riveting. In fastening together two overlapping plates by this process, the two electrodes are pressed, one above and one below, on the spot to be welded, and the current passed until a sufficiently high temperature is produced. The pressure is maintained during cooling, after which the work is brought forward and treated similarly at another spot. It is quite possible that spot welding may supersede riveting in shipbuilding, as the process can be applied to thick plates. An extension of the spot-welding process is to unite the plates along their whole length, by passing through rollers which form the electrodes, the rate of travel being such as to allow each part to attain a welding heat. So far, continuous seam welding of this kind has been applied only to comparatively thin sheets.

The foregoing electric methods are all based on the heating effect due to resistance. The high temperature produced by the electric arc is additionally utilised for welding, and has a varied and rapidly extending application. The carbon arc, which yields a temperature of 3700° C., is used for welding seams, the procedure being the same as when the oxy-acetylene flame is used as the source of heat. Direct current is used, the work being connected to the positive pole and the carbon to the negative. It is customary to work at a pressure of about 90 volts and a current of from 50 to 500 amperes, according to the size of the work. An adjustable resistance is used to regulate the current, and the carbon rod is held in an insulating holder, forming a handle by which the workman moves the arc along the joint. It is not attempted to bring the work to a higher temperature than is necessary for complete fusion, but this condition is brought about more rapidly by the carbon arc than by any other source of heat, and the method is much used in the production of seamless steel drums, etc.

A more recent development of arc welding consists in the substitution of an iron rod as negative electrode in place of the carbon, which is fused by the heat, and the fused metal carried across the arc on to the work opposite. The iron electrode, which is usually coated with a flux to prevent oxidation, is rapidly used up, and must be continuously moved forward by the welder to maintain the correct length of the arc. The deposited metal is hammered during cooling, and very satisfactory joints are thus secured. The best voltage to employ is as yet an unsettled question; in American practice 45 volts are commonly used, whilst in this country pressures ranging from 75 to 110 volts are general. Iron-electrode welding is particularly useful for repairing cracks in boiler-plates or shafts, the procedure in the latter case being to cut away the metal adjoining the crack on either side, forming two conical pieces meeting in a point. The part cut away is then filled in by the arc, commencing at the narrowest point and working outwards. Fig. 2 shows the method applied to the filling in of the worn parts of a tram-rail, a repair of this kind often saving the cost of a new rail. In all arc welding the eyes of the welder must be protected from the rays of the arc, and suitable glass screens are therefore provided. One advantage claimed for arc welding in the case of boiler repairs is that, owing to the heat produced being intensely local, a joint may be made without caus-

FIG. 2.—Repairing a tram-rail by arc welding, using an iron electrode.

ing strains in the vicinity, as may be produced by flame welding.

Thermit welding finds its chief application in work on large sections, such as rails and thick shafts. In welding together the ends of two consecutive rails, for example, the rails are made to touch, and a refractory mould is placed round the two ends. The thermit mixture, consisting of powdered aluminium and oxide of iron, is fired in a crucible by the ignition of a small quantity of a mixture of barium peroxide and aluminium, the reaction resulting in the production of aluminium oxide and metallic iron at a temperature of about 2500° C. The molten mass is run from the crucible into the mould, the quantity being such that the lower part of the rails is surrounded by molten iron and the upper part by the fused alumina. After a short time longitudinal pressure is applied to the rails, which are now at a welding heat, and complete union is secured. After removing the mould, the thermit iron is left adhering to the lower part of the joint and the slag broken away from the upper part. This is now the common method of welding rails, and forms a typical example of the use of thermit.

In comparing the various methods of welding, it may be said that each has its special advantages and is preferable for one kind of work. When a choice has to be made in a case in which the work could be executed by several methods, the user is guided by experience as to which is likely to suit best, and also by cost and convenience. In all instances much depends upon the skill of the welder, and figures showing the strength of welds will not be realised in practice unless the work is carried out by a thoroughly competent workman.

C. R. D.

SULPHURIC ACID AND THE WAR.

MODERN warfare has been described as an affair of mechanics and chemistry. Of course, this is a very partial and incomplete definition, inasmuch as it neglects what, after all, is the paramount factor—the human element. But, given that the human factor is equally potent on both sides, it is certainly true that the belligerent which is most alert and most resourceful in the use of the methods and practical achievements of science will inevitably triumph in the end. The whole conduct of the war shows that our enemies have not been slow to appreciate this fact, and if we have been a little more tardy in learning the same lesson we are rapidly making good whatever leeway we may have lost.

Nothing distinguishes this war more markedly from previous campaigns than the manner in which the scientific knowledge and intelligence of the nation have been enlisted, both in its prosecution and in the repair of its ravages. We have a notable instance of this circumstance in the recently published Report of the Departmental Committee appointed to consider the post-war position of the sulphuric acid and fertiliser trades. Sulphuric acid is indispensable in war; a nation deprived of it, or of certain of the products which can be obtained only by its means, would be helpless in face of its enemies. It required, however, nearly nine months of actual warfare for those in authority in this country to realise the danger of a possible shortage in the supply of the sulphuric acid absolutely essential to the production of explosives, and a small but eminently competent committee of well-known manufacturers was at length appointed to advise the Government in the matter. The result was that the makers of sulphuric acid and its principal users were organised in view of the national emergency. The request that the demands of the explosive factories should receive priority was willingly acceded to, and it is satisfactory to learn that their requirements were fully met.

The enormous amount of sulphuric acid of high strength needed in the manufacture of explosives has, however, led to an extraordinary development in the industry, and to many far-reaching changes which those who are charged with the consideration of questions of what is termed "reconstruction" view with no little apprehension and concern. Concentrating plants on a large scale have been everywhere erected; large oleum plants have been constructed in connection with Government factories, and private manufacturers have been encouraged to extend their chamber plants and to work them continuously and intensively. The result is that the productive power of the country has now reached an amount greatly in excess of the pre-war consumption, and the problem which the Committee has had to consider is how this expansion can be dealt with in view of possible post-war requirements.

If the outcome of the war is to lead to the continued existence of militarism, the Government explosive factories with their contact and oleum plants will have to be maintained, for it is inconceivable that we shall revert to the fatuous policy of letting things take care of themselves, and of not foreseeing and making provision in advance, which prevailed at the outbreak of hostilities. As regards private manufactories of concentrated acid and oleum, it is to be expected that the resuscitation of the synthetic dye industry in this country will continue to absorb an increasing amount of these products. We may hope that it will prove to be one more instance of a superfluity in supply creating a new demand. But, however optimistic one may be in this respect, it can scarcely be doubted that for some time to come the supply will greatly exceed the demand, and that much plant will lie idle and may possibly be "scrapped."

There is at least one new source of sulphuric acid in this country, created by the war, which it is greatly to be hoped will be maintained and extended, and that is the production of acid from Australian zinc concentrates. The manufacture of zinc was instituted in this country before it was started in Belgium and Germany, but it has not been developed here to anything like its proper extent. Although London is the chief zinc market