Modern Welding by Electricity*

Principles, Advantages and Recent Developments

THE use of electricity as a means of welding or cutting metals, repairing cracks or breaks, recovering defective castings and for similar purposes, all generally included under electric welding, has only recently been realized to any extent by manufacturers and engineers. Although comparatively simple in theory, the development of the use of electricity in this form has been slower than any other service to which this power has been applied. This slow growth can be attributed to several causes, the principal ones being the scarcity of skilled operators and suitable apparatus for performing the operation, and the lack of accurate information on the different methods and their application.

During the last two years the scarcity and high cost of labor and materials have forced many firms to accept this method as a measure of great conservation or higher efficiency or both. Once in use its value is quickly recognized and the impetus thus lent undoubtedly assures electric welding a prominent place in the electrical field of the future. This development has already resulted in many improvements in the design of the aparatus used in this work by the different manufacturers and in the elimination of many other difficulties which were encountered in its application. The extent of its field, however, is by no means realized as yet and this is largely due to ignorance of its application and use.

The subject of electric welding may be roughly divided into two sections. These are alike inasmuch as they both use the heat generated by an electric current to bring the metal to the proper temperature for the work. The methods which they employ to produce this heat and the processes which are followed in applying it are radically different, however. Furthermore, each has its field and limitations and these, although overlapping in some instances, are so clearly defined that the two methods do not conflict in general usage. One of these methods is known as the electric arc-welding process, the other as spot or butt welding.

The first method to be treated is the electric arc-welding process. In this process the intense heat produced by an electric arc is used to bring the metal to a melting or fusing point. The flame thus created, in addition to being the hottest flame yet produced, is concentrated which permits of its application to any desired point. In modern practice this process is again subdivided into the carbon electrode or Benardos process and the metallic electrode or Slavianoff process which were first introduced about 30 years ago.

Of the two common arc methods, the metallic electrode or Slavianoff process is more generally used, although both cover a common field and the use of either is largely determined by the individual requirements. As a matter of fact modern apparatus is usually designed for use in either process. In the metallic electrode process an arc is produced between the material to be worked, which is connected to one side of an electric circuit and a rod, usually of the same metal, connected to the other side. The heat of the arc thus produced melts the rod and heats the material sufficiently to unite with the particles of metal deposited from the rod.

In the carbon electrode process the arc is drawn between the material and a carbon or graphite electrode, the metal to be deposited or filler being supplied from an outside source, fed into the arc and thus melted. Where desired, this form of arc can be used to cut the metal by burning it away.

As was stated, both of these methods cover the same general field and the selection depends upon certain features of the individual case to which they are to be applied. The metallic electrode process is generally preferable for use where the current required ranges between 25 amp. and 150 amp., although as high as 225 amp. has been used by this process. Satisfactory results cannot be easily obtained with the carbon electrode if the current used is below 300 amp., as the greater heat which it generates tends to burn the metal. In addition, the use of this electrode tends to carbonize the metal which may seriously affect its strength. However, where the material to be welded is heavy or the weld of considerable size and the strength of the resultant weld is not especially important, this electrode may be used to advantage as it is much faster than the other.

In the majority of present applications of both of these processes direct current is used at a pressure of between 20 and 50 volts across the arc. Alternating current has also been used with considerable success, but due to the low power-factor of the welding load it is not used as generally as direct current. The advocates of this class of service in arc welding however, claim many vital advantages for it and as the use of welders is advanced no doubt it will more closely compete with direct current in the extent of its field. The application with either form of service is the same, except that more skill is required in using the latter.

The low voltage required can be obtained by the insertion of resistances across any available line, but, as this method entails a considerable loss of power, special generating equipment designed to deliver the current at a much lower voltage than ordinary has been developed. This equipment for direct-current service usually consists of a generator equipped with the proper driving device, either an alternating-current or direct-current motor or a pulley for connecting to an existing mechanical power supply, the generator being designed to deliver a heavy current at about 60 volts and the whole motor-generator set being provided with the necessary resistance and control apparatus. A number of manufacturers have recently made several radical changes in this apparatus with the intention of securing a much more uniform supply and thus stabilizing the arc. For use on alternating-current circuits this change in voltage is easily accomplished by means of transformers.

PREPARATIONS FOR WELDING.

The application of electric arc welding may be divided into three distinct operations; preparing the material to be welded, striking or starting the arc, and manipulation of the electrode, filling material and the work being welded.

The proper preparation for the work is of the utmost importance. Scale, grease, dirt, etc., should be entirely removed if the resultant weld is to be free from impurities. To accomplish this the work must be first gone over thoroughly with a rough file, rasp or wire brush and where necessary a light chipping may be made over the surface to be dealt with. It is often desirable to use a sand blast to accomplish this cleaning and in many instances the impurities have been burned off with a carbon electrode arc.

The next step is the proper shaping of the surface of the material for the weld. This preparation varies widely for individual requirements but should be given adequate consideration in every circumstance. In many cases preheating of the metal may be necessary and in these cases a temporary furnace will have to be provided.

After the material is properly prepared it can be connected to one side of the welding circuit. In both methods, but more especially in the carbon electrode process, the material to be welded is connected to the positive side of the line and the electrode to the negative side. It is known that a much larger percentage of the heat of an arc is developed at the positive than at the negative pole and consequently this method of connecting is employed in order that this greater amount of heat may be applied where needed, namely, on the material being welded. In addition, experience has demonstrated that if the flow of current is from the weld to the electrode particles of unconsumed carbon from the electrode will not be injected into the weld. If these connections are reversed, a very unstable arc, a spongy deposit on the weld and a very hard and scaly weld are apt to be the result.

The selection of electrodes and material is the next step in completing the weld. There is a distinct type of holder designed for use with each type of electrode. The carbon electrode holder, on account of the intense heat generated by this process, is much heavier than the metallic electrode holder. The cables connecting to the holders and the work should be of sufficient size to carry the desired current without any appreciable loss and sufficiently flexible to permit the operator to move them about freely.

In choosing the size and types of electrodes for use on various jobs the character of the work will ordinarily be the deciding factor. The following table represents the size of iron or steel metallic electrodes for use with various current densities and the approximate thickness of the metal to be welded:

Diameter of electrode.	Maximum current.	Thickness of plate.
1/16 to 3/32 in.	75 amp	⅛ in.
⅛ in.	125 amp.	½ in.
5/32 in.	155 amp.	⅝ in.
3/16 in.	175 amp.	above ⅝ in.

The wire for these electrodes must be free from impurities and especially the amount of carbon, manganese, phosphorus, sulphur and silicon which it contains must be kept as small as possible.

The filler to be used with carbon electrodes may be classified in the same way as metallic electrodes. The proper size of the carbon to be used in this work may be determined from the following table:

Diameter of electrode.	Maximum current.
¼ in.	100 amp.
½ in.	300 amp.
¾ in.	500 amp.
1 in.	1,000 amp.

The use of a flux in welding is advocated by many authorities. The theory of the functioning of the flux is that if carbon is introduced into the weld from the carbon electrode, it will unite with the oxygen of the flux and disappear in the form of carbon dioxide, leaving the pure iron in the weld.

The actual welding process is started by the operator touching the electrode to the work and instantly withdrawing it a sufficient distance to maintain the arc. This is commonly called striking the arc. The distance which the electrode is withdrawn differs in the different processes. In the metallic electrode process the arc cannot be maintained if more than about 3/16 in. long and should be preferably kept as short as possible as the shorter the arc is kept the less possibility there is for the various detrimental gases to creep into the weld. This makes this method of welding much more difficult to perform than the carbon electrode process in which the length of the arc should be at least 2 in.

After striking the arc the metallic electrode is woven slowly over the place to be welded in order to bring the metal of the material and electrode to the proper condition at the same time. With the carbon electrode the arc should be played over not only the actual spot to be welded but the surrounding metal as well in order to heat the whole surface adjacent to the weld suficiently. When the metal becomes molten, the flux, if any is used, should be applied, and the filler material should be gradually fed in.

In this manipulation of the arc special attention must be given to the effects of the expansion and contraction of the metal. Owing to the fact that in the case of electric arc welding the heat is quickly applied and confined to a very small area these effects are very apt to prove dangerous. Several methods have been introduced for combating this condition, nearly all of which follow the general method of keeping these stresses at a minimum. For example, in welding a square patch, the top portion is welded first, then the side connecting the top and bottom and at which the previous welds were started and then the remaining side. In this way, all parts are allowed to cool before the next weld is started and the strains are reduced.

As soon as the metal of a weld begins to cool, it should be hammered, in order to prevent sponginess and to give the metal a finer grain and to equalize the strains.

On account of the serious effect of the ultra-violet rays which are created in an arc drawn between iron and iron or carbon and iron it is absolutely essential that suitable protection for the operator and others in the vicinity be provided. The rays produce an effect similar to sunburn on any part of the body and are dangerous if viewed with the naked eye, not only because of this actinic property but also because of their blinding brilliancy. For this reason every part of the operator's body should be covered and heavy gloves should be provided. Protecting booths should also be erected to cut off these rays from other workers in the vicinity. A light metallic headgear or hood designed to completely cover the head, face and neck of the operator with a suitable glass opening which will permit the operator to see the work but is so equipped as to absorb these dangerous rays should also be provided. This is usually accomplished by using a series of suitably colored glasses. A combination of glasses which has proven very satisfactory is, two red glasses and one green glass. A clear glass is usually put on the outside to protect these glasses from being pitted by the flying particles.

Electric arc welding, more than in any other process in which electric power is used, depends upon the skill and carefulness of the operator to produce successful results. For this reason extreme care should be taken in the selection of welders. Only men with

*From *Electrical Review*.

previous experience in similar work, such as boiler makers, blacksmiths, etc., who have proven to be neat, careful, and reliable, should be chosen for this work. These men should then be given an extensive training in this work before being allowed to actually do any welding.

The value of such training was recently given considerable prominence by the establishment of a school for welding operators by the United States Shipping Board which has been very successful in the educating of men for this work. Mere knowledge of the operation will not suffice, however, unless the operator is careful, reliable and takes a certain amount of pride in his work. For this reason, every effort should be made to instill into the men the vital character of these features. Once selected, welders should, if they prove successful, be kept permanently employed. One plan which has given considerable success is to let the welder act as a superintendent in the cleaning and preparatory process, performing only the actual welding himself. Another, is to keep an accurate record of the welds made and the welders.

As was stated, the adoption of this method of welding by the Emergency Fleet Corporation brought it into considerable prominence and gave a decided impetus to its development. The information distributed by the Welding Committee appointed by this corporation, under the able leadership of Prof. Comfort A. Adams, president of the American Institute of Electrical Engineers, has been invaluable in the elimination of many of the difficulties which formerly retarded the growth of this method of welding and in developing many new phases of its application. The perfecting and adoption of the standard form of nomenclature to be used in designing and standardizing arc welding is but one of this committee's many notable achievements.

Although the use of arc welders was given prominence by its use in shipbuilding the largest field of its former and probable future activities is in the shops of the railroads, both steam and electric. In parts of this field it has been used quite extensively for years in repairing broken parts of engines, worn track frogs, crossings, bearings, axles, wheels, etc. It is now being used in the construction and maintenance of locomotives, cars, etc. A number of railroads are now making preparations to adopt this system of welding more generally.

In addition to railroad and shipbuilding plants, practically every industry making use of iron and steel can utilize the arc welding process to advantage. The filling and repairing of defective castings by this method has enabled many manufacturers to effect considerable savings in this way for many years. To attempt to enumerate all the possible operations in which this method could be used to advantage is practically impossible, however, every firm using metals which can be welded to any extent, as well as repair shops, etc., will do well to invetigate this process and the advantages which it offers in their work.

SPOT OR BUTT WELDING.

The second method of welding by electricity is the so-called spot or butt welding. This method has been used for a number of years in the welding of small iron and steel parts and recently plates as large as 1 in. in thickness have been welded by this method. Contrary to the arc-welding process, spot welding can be easily done by an inexperienced operator and furthermore the designs of the different machines have been perfected for several years. The features which have retarded its growth therefore also differ from those affecting arc welding and can be attributed chiefly to two sources. The first is the lack of sufficient and suitable publicity given to this method and its apparatus. The second is the fact that as most of the installations use alternating current the extremely low power-factor and intermittent use of this welder make it a rather undesirable load. The advantages which can be obtained by its use, however, more than offset these undesirable load features and this method is also receiving considerable attention which promises a brilliant future for it.

In this method a large volume of current is passed at a low pressure through the contacting surfaces of the metals to be welded. The electrical resistance of these metals at the contact surface is so great that they become heated to a welding temperature. In spot welding this current is applied through two suitable electrodes, usually copper, which hold the metal firmly in place. When the metal is sufficiently heated, pressure is exerted on the parts forcing them to unite in welds.

This current is supplied to the electrodes usually from a transformer mounted on the welding machine which reduces the voltage to about 2 to 10 volts. The current required will vary, depending on the amount of resistance which the material to be welded offers, being very high if copper or similar conductor is to be welded and comparatively low for iron or steel.

The operation of a spot welder is very rapid, taking but a few seconds to produce a weld, and there is no preparatory work necessary except to clean the surfaces.

Butt welding is similar to spot welding and is generally classed with it as spot welding. The principal difference in the processes is that in butt welding, two pieces of metal are placed in jaws with the edges extending a slight distance beyond the jaws and in contact with each other. The same general process then follows. As a result, these edges are welded together over the entire contact surface, whereas in spot welding the welding is only done over a certain area and the metals held together similar to riveting.

The advantages to be derived from the use of either of these methods are too numerous to mention. Nearly all metals are adapted for use in this process although many will have to be treated after the operation either to restore them to their original strength or to repair the finish. Welds on iron made by these processes and subsequently tested, proved much stronger than riveting and compared very favorably with the strength of the metal itself. It is also much faster than riveting and much more lasting. Further, they are not affected by heat, which permits of its use in stoves, etc.

The use of spot welders is limited to metals of small size which can be brought to the machine for welding. Manufacturers of small metalware, etc., have found them a great aid in welding parts for many years. In addition, rivets of any size, after being set into rivet holes, may be heated and headed in one operation by the use of a spot welder, the results being much finer and more uniform than when the riveting is done mechanically.

The Fluorescence of Cellulose and Its Derivatives

It had previously been recorded by Hartley (Chem. Soc. Trans., 1893, 245) that cellulose in the form of white blotting paper is fluorescent and capable of rendering visible the whole of the ultraviolet spectrum as far as wave-length 2,000. This phenomenon has been studied by the author, and the effects have been recorded photographically to show the relative intensity of the degradation of ultraviolet light at various wave lengths to visible rays capable of passing through glass and affecting the photographic plate. Graphs have been constructed in which the intensities are plotted as ordinates and the wave-lengths as abscissæ. The general results show that the power and distribution of the fluorescent properties are definite functions of the chemical constitution, and their variations conform to what is known of the influence of substituent groups on the properties of the original substance. Normal cellulose, from whatever source it is derived, gives a fairly uniform spectrum, but the intensity varies with the specimen under observation. The cellulose from rhubarb stalk and cuticle falls in the same group. Modified celluloses, such as viscose fabric and parchmentised paper, show a considerable divergence from the normal; well beaten "bank" paper falls in the same class, which is characterized by a strong effect at a wave-length of 2,750. Ground wood paper (lignocellulose) is devoid of fluorescent properties, and the cellulose nitrates are nearly, if not quite, inactive. On the other hand, the acetylcelluloses exhibit a fluorescence which is generally much stronger than that of the normal cellulose, and which is much stronger towards the visible region than towards the extreme ultraviolet. For media of the same chemical constitution the resulting degraded spectrum is much the same for the transparent film through which the ultraviolet light is transmitted as for the opaque network in which it is reflected at the surface of the fibres.—*Note in J. Soc. Chem. Ind. on an article in Jour. Soc. Dyers & Col.*

To Make Liquid Indigo

To make liquid indigo the indigo plant, after being cut and gathered, is first placed in casks, specially made with plugged holes in the side, which are filled with water. After soaking a few days lime is added, and in about one week's time the stem and branches of the plant are removed. Each day the contents of the cask, after being well stirred and beaten, are allowed to settle, and on the following morning, before this process is repeated, some of the plugs are removed, allowing the water above the sediment which had formed overnight to escape. Gradually the water is thus eliminated and liquid indigo is found in the bottom of the casks. These casks vary in size, some of them being as large as 12 feet deep by 10 feet in diameter, and are made of thick pine boards held together by bamboo hoops.—*Engineering.*

A New Method of Repairing Ships

A novel ship repair job has been recently carried out in Buenos Aires. The ship was a wooden vessel called the Paloma Argentina, of some 200 tons displacement. The wooden ribs of the vessel were quite rotted away at the bottom, and the repair consisted in casting in armored concrete ribs between the existing wooden ribs, the ribs being bonded to the skin by coach screws driven partly into the latter. Here and there extra deep concrete ribs with special reinforcement were taken over the inner or false keel. The repair is reported to be quite successful, and as the concrete takes the place of ballast, has added nothing to the weight of the vessel.

SCIENTIFIC AMERICAN SUPPLEMENT

Founded 1876

Published by Scientific American Publishing Co.

New York, Saturday, March 1, 1919

Munn & Co., 233 Broadway, New York

Charles Allen Munn, President; Orson D. Munn, Treasurer
Allan C. Hoffman, Secretary, all at 233 Broadway

The Scientific American Publications

Scientific American Supplement (established 1876) per year $5.00
Scientific American (established 1845) 5.00
The combined subscription rates and rates to foreign countries including Canada, will be furnished upon application.
Remit by postal or express money order, bank draft or check.

Scientific American Publishing Co.

233 Broadway, New York

The purpose of the Supplement is to publish the more important announcements of distinguished technologists, to digest significant articles that appear in European publications, and altogether to reflect the most advanced thought in science and industry throughout the world.

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