

THE PRACTICAL ASPECTS OF ELECTRIC WELDING.

BY FREDERIC A. C. PERRINE.

It is hardly necessary to give any description of the general process of electric welding to the Institute of Electric Engineers, or to follow Mr. Lemp's paper of last year and our interesting visit to the factory of the welding company, with a detailed description of the machines. I intend rather to speak of them in their actual use, and to discuss some of the problems involved.

The plant with which I have been intimately connected, though not one of the heaviest, is still one making a great number of successful welds in a day, and is one in which the joints are required to be of the highest character and are subjected to the severest tests. The first machine actually leased by the welding company was taken by the Roeblings; but on account of the delay of the engine builders it was not in place and running for some six months—three or four months after other machines were in satisfactory operation. This was of the direct type, having a double winding on the armature, and the welding done on an apron immediately above the collector terminals of the heavy alternating coils. The pressure was applied by a handle regulated by the workman, the projection also being regulated by a scale stamped on the cam of the handle. Though considered crude, this machine did satisfactory work, often for twenty-four hours a day, and six days in the week, for about two years, having made about 370,000 splices in telegraph wire during its useful life.

After the automatic machines were brought to a reasonable perfection, we purchased a generator capable of welding up to $\frac{1}{2}$ in. copper (40,000 watts), and installed one large trans-

former and seven smaller ones of capacity from No. 4 B. & S. copper to No. 18 B. & S. These have been at the works something less than one year, and show a daily record of over 1,000 welds in copper and iron wire.

Our attention was drawn to the process at first as a possible solution of a very troublesome problem in preparing and packing iron telegraph wire. For the convenience of the telegraph companies, this wire must be put up in bundles, measuring each exactly one-half mile of continuous length. It is very easy to say that the proper weight billets be bought and the pieces kept continuous through all the processes of manufacture, but as a fact these pieces are necessarily irregular in original size and are often broken in the process of manufacture and, in consequence, it has long been the custom to make the proper weight bundles by re-coiling and splicing with the common telegraph or Lippman's joint, after the wire has been galvanized, jointing before galvanizing having proved a failure, on account of the acid carried over into the zinc pans by the great helix of the joints.

Singularly enough, the telegraph companies which had for so long accepted as satisfactory these cumbrous connections, immediately commenced to complain of the large burr left by the welding machine, and which we had thought unnecessary to remove. An emery wheel solved this difficulty, however, and we were then able to defy them to find the joint at all. After a very complete series of tests on the joints themselves, the telegraph companies have been finally satisfied and we are now able to make our bundles of the proper weight and length before the galvanizing is put on and thus save one rehandling of nearly our whole product, besides having removed one of the greatest difficulties and causes of complaint.

"Shorts," as they are technically termed, in copper, are of course a still more serious source of loss, not only on account of the greater value of the material, but also on account of the greater liability of this weaker metal to break in the process of drawing, and also on account of the necessarily defective character of a joint in the insulation with which copper wire is usually covered when sent out from the factory. Cables, as you all know, must be made in exact lengths, many of which are often very great, and though a twisted soldered joint might be satisfactory at the bottom of the sea, or covered by a lead sleeve in a man-hole, it could not for an instant be tolerated in the body of a

cable which must, before completion of the cable, be passed through exact dies for covering with rubber or lead. Before the introduction of these machines, our custom had been to carefully scarf and fit the joint which was then brazed with silver solder. While this method makes a strong joint, but little increased in resistance and thoroughly satisfactory in other respects, it has the disadvantage of being rather slow and difficult to produce on account of the necessary care in fitting the scarfed ends as well as in soldering and finishing.

Since last November three boys on three machines have made respectively in this work 10,570 welds, 7,642 welds and 20,421 welds, the registers having been taken on April 16th. Every weld is tested by bending and straining, and if one shows any weakness it is quickly cut out and made again, with the loss only of a very small amount of time and the royalty to the welding company. In all of our welding of sizes below $\frac{1}{4}$ inch, the ends are prepared by cutting square across with a pair of pliers, and then setting the cuts at right angles to each other, touching only at the centre from which the heat radiates to the surface; then, after completion of the weld, the burr is removed by an emery wheel from the iron wire, and by a file from the copper. The preparation and finishing is a little more complex in the larger sizes, the ends are filed to a true butt and chamfered at the edges and after a reheating in separate clamps the burr of the weld is forged to the diameter of the original rod. The necessity of this will be apparent later on. All of this work is done on either soft steel or copper wire, and is probably of the simplest character done on any machines made by the welding company, consequently the advantages are not so apparent as where the welds are difficult in character on account of complicated shapes.

More varied work is done by the companies of whose plants I now give slight descriptions as likely to prove interesting.

Messrs. Seward & Son of New Haven, Conn., have at work a machine of somewhat universal character, its employment being principally in uniting Norway iron to Swedish steel in such shapes as are required in carriage irons and fifth wheels. In this work the burr is removed by a drop-hammer at the same heat by which the weld has been made.

The crescent tires of the hundreds of bicycles manufactured by the Pope Manufacturing Company, are welded and afterwards formed by dies at the same heat. The material is soft

steel. These people also have a machine for brazing their small parts.

Besides using the electric welding machine for their telegraph wire, the Trenton Iron Company of Trenton, N. J., have boldly attempted to make a weld in a wire rope to avoid the tedious and, with their locked wire rope, impossible operation of splicing. The ordinary joint in a wire rope is from ten to twenty feet in length, and requires considerable skill on the part of the splicer and his assistants. The operation is to re-twist bunches of wire from opposite strands, and to tuck the loose ends under the adjacent complete strands, which then hold them in place. With the locked wire rope, which is itself but a single strand, the only successful method of joining opposite ends has been to fasten securely around each a cast-iron collar, and after abutting the ends in a welding machine, to cement the whole together and afterwards to break off the cast-iron collar leaving the rope as a solid bar for a short distance at the weld.

Among the new solutions of old problems accomplished by the electric welding process, is that of the manufacture of spinning-rings by the Hopedale Machine Company of Hopedale, Mass. The desideratum of these rings is a uniformly hard surface, to produce which the method has been to stamp the ring from a sheet of metal and after finishing in a lathe, to caseharden the whole, involving, as one would naturally see, the loss of a considerable proportion of the original sheet. With a welding machine it is possible to form these little rings, about $2\frac{1}{2}$ inches diameter, from a piece of bar iron, and after the burr has been reduced by a series of dies, to finish as before, with the result of a decreased cost and an equally satisfactory product.

One of the largest and most complete plants at present in operation is that of the Studebaker Bros. Manufacturing Company of South Bend, Ind. They have at present nine machines, one of them for steel axles up to $1\frac{1}{2}$ inches square. After the weld is made it is quickly removed to a drop-hammer making about 300 blows a minute; then at the same heat the axle is set ready for the market. The test for these axles is to bend to 90° while hot, and then back to alignment. No instance has yet been reported of an axle breaking under this test, which is frequently made to insure perfect workmanship.

They have two machines for welding large car tires, about 4 inches wide and $\frac{3}{4}$ inch thick, and smaller sizes. The weld is

made in the usual way and then quickly removed to a hammer where by vertical and side blows the burr is quickly removed. One hammer will easily take care of two welders in constant operation. They also have one machine for small carriage tires, 1 inch by $\frac{1}{4}$ inch, and smaller sizes. In this case the burr is removed by one blow of the hammer, after which the tire is set cold by a machine they call a cold stover, which embraces the tire on all sides and by great compression sets it up to the fellow more quickly and as effectually as can be done by shrinking in the old method. This, of course, is an immense strain on the weld, being a compression beyond the elastic limit of the metal. They have two machines for the hub bands which are used on the wagon wheel, and they are able to turn out about 1,200 on each machine. Besides these, there are two or three machines for smaller miscellaneous work. All of the metal used by them is either iron or low grade steel. After the introduction of their plant their machines made 360,000 welds inside of six months.

Probably the heaviest work done at present in electric welding, is that of the Johnson Company of Johnstown, Pa., who are not, as stated in the journals, welding long lengths of rails together, since with their continuous mill they already roll a rail too long to ship, but they find economy in the process in some details of their smaller manufactures. As to their results in general, they say: "We would state that over a year ago we put in one welder for general work. The bulk of the work done on this machine was work we had totally failed to do by hand welding, not on account of the difficulty of the weld, but on account of the general unreliability of the result. The result of a year's use of the electric welder was that we have not known one of the welds made by the method to fail, and we have closed contracts with the welding company for four 40,000 watt machines and two 80,000 watt machines, with the intention of adopting the method extensively in our works."

Agricultural machinery has generally been furnished with iron wheels, consisting of a malleable iron hub into which the spokes are upset, and of a rim into which they are upset at the opposite end. The electric welding machine has given us two new wheels, each of which are supposed to be preferable to the one described. In the first, manufactured by the Electric Wheel Company of Quincy, Ill., the hub is cast of malleable iron, with spokes about 3 inches long. To these are welded, by one machine, wrought-

iron spokes, and again by another machine these spokes are upset into the rim, which is itself welded into a tire, the product being a wheel of which the spokes are less liable to rattle loose at the hub. The second method is that of Niles and Scott, La Porte, Ind. The hub in this case is composed of two drop-forgings of low grade steel, grooved to receive the spokes. One-half is placed on the base of the welder and the spokes laid in their grooves; then the other half of the hub is put on and the clamp brought down. The current is then applied and the whole, spokes and hub, welded solidly.

The Rogers Typograph Company, Cleveland, Ohio, are practically welding brass to steel, making as high as 800 welds per day, and thus effecting a great saving in the manufacture of their type-setting and founding machines.

The hardest steel at present successfully worked by this process is the welding of band saws by the E. C. Atkins Company of Indianapolis, Ind. Besides the regular work of making the joint in continuous band saws, these people have ingeniously adopted this method for replacing broken teeth in finished saws. Formerly they were compelled to cut down to a smaller size any saws from which one or two teeth had been accidentally broken, thus losing not only the difference in price between the two saws but also the entire cost of labor in cutting the original saw. At present when a tooth is broken out, they fit in it a new tooth, which is electrically welded in place, and a drop of oil applied at the completing of the heat restores the temper to a serviceable point.

This, one can readily see, is of the greatest value in reducing one of the sources of imperfect work.

Pipe welding, which we all saw successfully accomplished at the factory last year, is put in practice by the Pennsylvania Railroad Company as well as by the Columbus Iron Works, Columbus, Ga.; Blymyer Ice Machine Company, Cincinnati, Ohio, and the Electric Pipe Bending Company of Harrison, N. J. This latter company is engaged principally in manufacturing long continuous coils for ice machines, blast furnace tuyeres and radiators. With this machinery they not only weld extra heavy black pipe, but also electrically heat the pipe with a machine 28 inches between the clamps for the purpose of bending to desired shapes over pipe formers.

With continuously spiraled coils of pipe it has been necessary

for a smith to weld the whole length, 150 to 200 feet, before attempting to bend any portion of it, and then after once the bending operation has commenced, in order to get a uniform spiral, the heat is not altered or the bending operation suspended till the coil is complete. Under the present electrical methods the coils are continuously heated in a fire, and the coiling is continuous while one length of pipe is welded at a time, the operation being to attach the welding machine to the end of the moving pipe, and while the forward portion is undergoing the process of bending, to weld on a new length, which will be accomplished in a sufficiently short time not to interfere with the coiling apparatus. In all of this pipe welding the burr is beaten down by means of a pneumatic hammer which is put in rapid motion by the act of closing it around the pipe, a rapid hammer having proved much more effectual than any press or dies. This is probably on account of the more rapid cooling action of the press, since no forming is attempted before the weld is completed and the current is turned off.

Three types of machines of importance are soon to be in use for the purpose of our army and navy, and the early recognition of the importance of this method of manufacture, speaks well for the ingenuity of our government designers.

In the new wire-wound guns, one of the most important specifications for the wire was that it should be readily jointed by the electric welding process, and in the Crozier gun now constructing the wire will be wound in one continuous piece under a constant and heavy strain. This wire is one-tenth inch square, with 180,000 lbs. breaking-strength, and 100,000 lbs. elastic limit, tinned as lightly as possible. The gun is to be made by winding the wire over a steel tube and shrinking a ring over the whole for the purpose of longitudinal strength. The welding process is simply the same as that described for round wire, and is reported as having given satisfactory results.

For the Charlestown Navy Yard, there is about completed a machine for welding ship chains up to 2 in. diameter links. These links are formed in halves and fitted roughly to each other, the welds being made in both sides at once by the same heat, which can be regulated to force either side at the will of the operator. When completed, both welds are forged immediately in a die by the same hammer. By this method only the points to be welded are heated, and as these are immediately forged one could expect

from the process a nearer approach to the strength of rolled metal than where the whole link is heated in the ordinary fire to a welding temperature.

The latest development for government work is the manufacture of conical shells and shrapnel for the smaller armor-piercing guns. With the modern type of armor, a cast shell is not of sufficient strength to resist the shock of impact and in consequence a chrome-steel point is welded to a tool steel body, embracing the powder cavity. This latter is but small in comparison with that in the old round shell of revolutionary days, consequently the accurate forging of the interior becomes correspondingly difficult.

Cast shells are made from the higher grades of crucible steel, but with these the casting is both difficult and uncertain, necessitating a large amount to be allowed for machining to a uniform wall in the probable case of a decentered core. The electrically welded shells are made entirely of forged point, body and base, which may be finished to approximate dimensions, these requiring after welding a minimum amount of machining. The tests on these shells have resulted in a contract for a large number under a guarantee of the manufacturing company.

This brief sketch of the representative uses of the process, I have given not only to show the practical applications of electric welding, which are undoubtedly interesting in themselves, but with this introduction I wish to call attention to some of the limitations and necessary precautions, as well as to the light which the results of this method of applying heat to the metals throws upon some of the obscure and disputed points of structure and constitution.

Welding in the ordinary sense, on an anvil by the means of a forge, is essentially the uniting of two surfaces of a metal which has previously been rendered plastic and which, under the hammer, can be made to intermingle into a structure similar or identical to the original metal; in consequence, this can only be accomplished with materials capable of passing into a plastic state before actual melting takes place. One of the most familiar examples of this weld to electrical men is the common splice in the gutta-percha core of a submarine cable. Provided only that the surfaces are clean, it is possible to make this material unite as perfectly as before it was cut. Amorphous waxes and similar substances can be treated by a like method; but when we reach

truly crystalline materials it is no longer possible to effect this union below the melting point, unless great pressures are applied. In passing from the one to the other condition, we see the phenomenon of the familiar cementing of ice under pressure great enough to produce what is called regelation.

Now, viewing metals in the light of these simple examples, we find that it has long been possible to weld amorphous iron under moderate heat, but for the highly crystalline steels and other metals a pressure high enough in ordinary practice has not been available.

Welding cold has been accomplished in a most striking manner by Professor Spring of Liège. Using small cylinders filled with powders of highly crystalline metals, he has not only succeeded in compressing them into compact bars, but has also succeeded in making alloys with all the characteristics of the same alloys produced in the usual manner in a crucible. These results go very far towards proving the absolute possibility of a weld in any material, however fibrous or crystalline. The electric welding process uses rather the method of the crucible than of the press, for although considerable pressures are applied during the operation, they are not beyond the limits of ordinary forging, and the essential difference is the greater heat available at the direct point where it is most needed, a heat which approaches and often reaches the melting point of the material. As the pressure is applied it is transmitted by the cold bar directly upon the softened metal and forces it to unite more readily. This view of the process brings us at once to some of the most important limitations; cast-iron, cast-steel, cast-copper, cast-brass are not changed in their essential constitution, but are united by a weld having all the characteristics of the original bar. Now, let us take a bar of rolled zinc or drawn copper and compare it with the cast metal. We find the crystals, formerly large and widely separated, especially in the case of zinc, where often internal oxide stains are perceptible, are now broken into minute fragments, elongated and united so closely as to allow the greatest opportunity for the action of cohesion. Weld such a metal as this, and the joint where broken will immediately show a rearrangement of the particles into larger and looser crystals, similar to those of the unworked metal. By repeated fracture of the bar you will be able to follow graduations of the action till it loses itself.

A weld of this character will give a sufficient tensile strength,

but the brittleness of a coarsely crystalline material has returned. Whether such a joint is worthless is entirely a matter of circumstances. With small sections the action is not perceptible on account of the very small length heated and also because bending, however short, does not subject the metal to so great a strain as in the case with larger sections. For a rod to be subjected to further drawing, rolling, or other like processes of manufacture, the weld is satisfactory, since the subsequent working reinstates the metal to its best condition, but for a wire to be considered a finished product further manipulation is necessary. In view of this, the later machines for welding heavy copper have been provided with reheating clamps and light rapid hammers, by means of which the burr, after a slight trimming, can be reheated and forged. In special cases a further hammering cold is added. Though this produces a great improvement in the metal, it yet leaves a good deal to be desired where great strength and pliability are required. To produce this a further upsetting of the metal throughout the whole heated space, and a subsequent forging will be necessary. This, up to the present time, has not been provided for and presents a greater difficulty than is at first apparent, besides furnishing a new proof of the crystalline constitution of copper. On account of this characteristic, as is apparent on attempting upsetting in the welding machine, it offers, at a red heat capable of moving and rearranging the particles, a resistance so high to compression that three or four times the pressure necessary for welding will not have the slightest effect towards increasing the diameter or upsetting. With bronzes the further difficulty is encountered of red shortness between the molten temperature of the weld and the malleable red temperature. That this should be so necessary and offer so many difficulties may seem strange, since the metal does not apparently exceed the temperature of ordinary annealing, and it must be that either the passage of the current by an extra disturbance helps to rearrange the particles, or else the temperature is greater than we imagine from an observation. The latter explanation seems to me to be the more likely, since our ordinary observations are made on metals heated from an external source and of which the surface is at the highest temperature. With the weld, however, the source of heat is internal and the surface is undergoing a continual cooling from the external air.

Welds made in the higher carbon steels are at a similar disad-

vantage and must be looked upon with disfavor unless provision for upsetting and forging hot is provided. These disadvantages are especially apparent with steel wires of the highest grade, where the strength of the original material has been more than doubled by tempering and drawing. In such cases it is not ordinarily the loss of tensile strength that is to be feared, but the increased liability to snap under repeated bendings. This is especially important in the case of wire to be twisted into a running rope such as is used on our cable railroads. From this view, the weld in a whole rope where forging is impossible, would be necessarily defective, and though for a standing rope I have no doubt it would be fairly successful, yet for a running rope I believe everything tends to prove it dangerous. It has been suggested as an explanation that these effects are due to the presence of oxygen at the weld, producing suboxide in copper and reducing the carbon in steel. In support of this view the case of the application of oil to the hard saw-teeth is cited as supplying the necessary carbon by its decomposition. It is undoubtedly a fact that by the heating of these high-grade steels and subsequent slow cooling some of the combined carbon is changed to the graphitic form, with a consequent loss of strength, and it seems clear to me that a drop of oil at the right moment serves to restore this or, in other words, effects a tempering. It is almost useless to attempt an explanation by a complicated chemical decomposition, when the simpler molecular rearrangement is more in accordance with the facts and a more complete explanation.

This brings us to a point where the electric welding throws light upon the actual production and nature of burnt steel. By forcing the heat in welding, no matter if rapidly, this effect can be produced as thoroughly as by the means of a fire, while if the name "burnt" was an accurate description and the iron and carbon oxidized, a sufficient time would be necessary for its penetration into the centre of a bar of metal. This agrees with and is a further confirmation of the most modern ideas about burnt metal, that it is a molecular rearrangement, and by careful forging and heating the metal can be restored to its original state. In this case oxidation certainly does not take place, though the action may be similar to metamorphism in rocks; steel being at the present day looked upon as a mineral, a matrix of iron including minerals which are generally compounds of iron with carbon, silicon, sulphur, manganese or phosphorus. Under this view

there may be internal chemical rearrangement at high temperature. With carbon we know this to be the case, but I take it as settled by electrical heating that the change is not necessarily an oxidation.

The welding of two different materials, such as iron and steel or malleable cast-iron, presents another difficulty and possible danger. When such a weld is broken we find that the pressure in the plastic state has forced the iron over the steel or malleable, which has itself been merely slightly melted and cemented to the adjacent particles of the iron. This produces what might be called a reverse riveting, the hot iron having been upset over the steel and inclosing it tightly, in the place of having been upset in a hole as in ordinary riveting. Again, as in all this work, the tensile test is but a poor test of quality, and though a weld may have within ten or twenty per cent. the tensile strength of one of the original materials, it is a fallacy to say that therefore the weld is within ten or twenty per cent. of the quality of either of them. Use here again determines the serviceableness of the process.

I am tempted here to carry further the discussion of the special cases offered, but it would only be to apply over again the observation indicated in the foregoing, and which might be finally stated that although the electric welding process will not practically splice everything from a bar of magnesium to a steamer shaft, yet it enables us to accomplish results otherwise impossible and if both the use of the product and the treatment of the materials be sufficiently studied, it may be trusted in its results.

DISCUSSION.¹

THE CHAIRMAN (Vice-President Hammer):—We shall have great pleasure, I am sure, in listening to Prof. Thomson.

PROF. THOMSON :—I would say, Mr. President and gentlemen, that my time has not been very closely given lately to the applications of welding processes in the arts. That department of the work has been very ably taken care of by Mr Lemp, whose paper the Institute heard last year. Of course, I have inspected the machinery as each type was brought out, and made suggestions constantly on this or that point, and may be considered, therefore, as a sort of privileged observer of results. There are gentlemen here also who may be able to give you more information in regard to the development of the business than I. I haven't paid

1. By Messrs. Thomson, Hammer, Maver and Lockwood.

attention to its details. I would say, however, in general, that the tendency in the development of electric welding seems to be to produce new processes or to give rise to new applications of mechanical principles, examples of which are seen in the wheels before us. There we have practically a development of a system of work depending entirely upon electric welding, and that seems to be the direction in which it is to grow most rapidly. Naturally, when it comes to supplanting ordinary processes of welding, there is that inevitable prejudice to overcome and at the same time the reluctance of the manufacturer to throw aside a plant which he already possesses and which does his work fairly—going to something entirely new—putting in an extensive electrical plant which he is afraid of, feeling that perhaps something may happen to it, and it may require repairs. He prefers that his neighbor shall get all that kind of experience before he takes hold himself. This is very natural, indeed, and it simply means that in certain directions the electric welding operations will probably be slower in development than they would otherwise be. But with the special cases, many of which you have had mentioned in the able paper presented, you can see for yourselves that there is a direct and easy growth.

In relation to the wheel before us, in which the cast hub is joined to spokes, there is one point that I may mention, that the possibilities are very well shown in that wheel, of performing a number of welds at one operation. There we have the spokes set in place in the machine and radiating towards the hub, and the machine grasping the spokes and welding them all at one application of current, so that we have a number of welds made in multiple, as it were. The other case is an excellent example of a different procedure, where the spokes radiate toward the centre and are caught and pinched between the two surfaces which are being welded, and are therefore securely fastened. These are some examples of processes capable of being performed in the new art.

In regard to the changes of structure which are undergone by materials subjected to the welding process, that was an effect noticed, of course, rather early. It was particularly prominent in the case of hardened steel, which underwent a decided change during the welding. Suppose the weld is made here (indicating). It would naturally be expected that whatever change was due to the application of heat above a certain temperature, would be found to have occurred in this metal at the weld. It would also be naturally expected that such action might proceed back from the weld a certain distance or, in other words, that if this bar had been tool steel, made under the hammer or in rolling, and had been thereby given a certain texture by the mechanical kneading or by the hammer, that a relaxation of such texture or a change of such texture might occur for a certain distance on each side of the weld. This is an actual fact. A tendency to

granulate exists there. The old idea was that the steel was burnt, but I have tried this operation in a hydrocarbon atmosphere and it occurs just as well in the hydrocarbon atmosphere, so that it is not a burning process. It is simply the relaxation of the molecules, the change of physical condition, or perhaps a different chemical combination brought about by the high temperature. To a certain extent this action occurs with other materials and, of course, with fibrous drawn copper it is present. Any metal whose properties depend upon the working, any metal a portion of the strength of which is due to having been drawn or hammered, of course undergoes that relaxation or rearrangement or tendency to granulation such as is found in a casting where the metal has undergone the melting process and has been allowed to cool afterwards. It is also a noticeable thing that we can take a bar of wrought-iron and put it in the welding clamps and pass a current through it, heating a portion, and so carry it to such a temperature beyond the welding temperature, as will actually change its nature. The bar can be made, by carrying it to a sufficiently high temperature, to become a spongy burnt mass—that is, the temperature will have been made so high that the iron, like the steel, undergoes a change of condition and does not re-

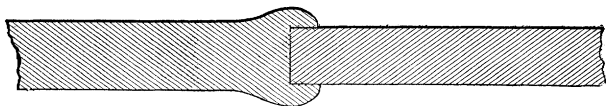


FIG. 1.

turn on cooling. I attribute this largely to the fact that in the ordinary operations of the working of the iron, the temperature has been below that point. The iron has been manufactured below that point in the furnace operations and that when we raise the temperature beyond the point of the making of the iron, we set free occluded gases which have been in the iron. We make the iron, as it were, puff out in a spongy form by setting free between the fibres the hydrogen gas, or at least in the substance, and consequently the iron breaks very easily there, and if examined it is full of minute cavities which show that occluded gases have been expelled.

Another interesting feature of the welding operation has been mentioned, which is that some materials when put together do not mutually yield during the heating; one, as it were, overlaps the other—the reverse riveting, as it has been termed by Dr. Perrine. One melts or softens and slips over the other, making a joint something like that [Fig. 1.] For many purposes, that is a very strong joint, particularly if the burr or expansion is not removed. There has been no change of form, or very little change of form of one of the bars. Even if one bar doesn't change at all, the union may still be a perfect one. It may be

that one piece, in fusing over the other piece, has brought about just the same intimate relation of molecules of one and the other bar, as though both had undergone a deformation or change. But in most cases it would naturally be expected that the best joint would be produced by, as it were, bringing to the front new molecules, perfectly clean and unchanged molecules, from the interior, in contact with the molecules of the other bar, which are also spreading and moving; and this is actually true. Advantage has been taken in a few instances, of the kind of action in which one bar only spreads, to make a joint something like this [Fig. 2.] Cut a number of steps in one metal and cause the other, as it were, to dovetail itself by a simple flowing over, and that in some instances makes an excellent joint. The metal flows over and fills the spaces all around, and if they have any tendency to unite, such as brass and iron have, or brass and steel, of course the union is very strong.

Another point in relation to the practical application of electric welding, and then I am through; and this is that it is curious to notice how prejudice sometimes stands in the way of the best results. There are undoubted cases where the burr or extension left by the welding operation would be best left on, because



FIG. 2.

there is an increased section there and unless this section is to be very well and heavily forged, the strength through the weld will be greater and the bar will rarely if ever fail through the weld; but from the mere habit of not seeing things done in that way, where the expansion would not do any harm if allowed to remain, people want it removed. It could in many cases be forged up to form a handsome bead, but in most cases, on account of prejudice, it must look like the ordinary scarfed weld or it is not altogether marketable. That, I think is a temporary condition for many instances of welding. It will be gotten over finally. Dr. Perrine has brought out the fact in relation to the telegraph wire, that where formerly they were content to take the double-twisted joint, with all the metal which is involved, and when they got an electric weld to take the place of that they were still not content. Their self-induction was high and nothing would satisfy them but that the slight burr should be removed, which was of course a simple thing to do, either by forging it down or by grinding it off.

One further point in relation to the upsetting for copper, the structure of which has been changed. This [Fig. 3] figure I make might represent a copper joint made of rather large cop-

per. Now, naturally if that joint has been formed, the copper has been heated back here some distance at a , on account of its high conductivity for heat, and if that part of the metal has a structure due to mechanical working, that structure is partly lost

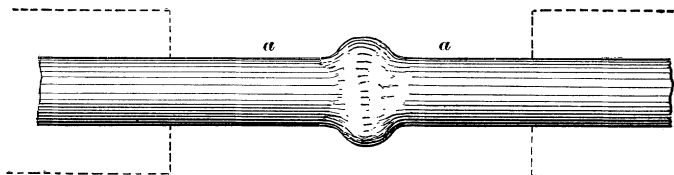


FIG. 3.

if not entirely lost at this point. It is desirable on account of the resistance to strains required for some puposes, that it should be restored. I found in the early days that I could, by taking the clamps apart a little, swell up a certain amount of material and then hammer the mass down to its original condition and get the effect of working back. But when this comes to be attempted on rather large stock, you can readily see that the power required is considerable. We must be able to take hold of that bar very firmly indeed, and we must have hydraulic pressure without any slipping, to force up a mass of material at a rather low temperature, because if you heat it to too high a temperature, the difficulty is that you do not upset the bar far enough back. You require to take in almost the cold metal in the upsetting process and then forge it back to the original shape to get the fibrous structure back. That probably can be done by taking hold of a sufficiently great length of bar on each side of the joint and by putting guides on each side of the work, so that it will not buckle out of shape and so take hold, in other words, at a number of points by multiple clamps so as to force the metal up. If we should use notched clamps, there is an objection at once, because we do not want an injury done to the exterior surfaces. We have to use a smooth clamp, a clamp which will not bite into the material and change its surface. We would probably have to take a foot or more of the bar, plant it firmly in clamps fitted closely to the work and then force it, risking the slip [Fig. 4]. Of course, we cannot get

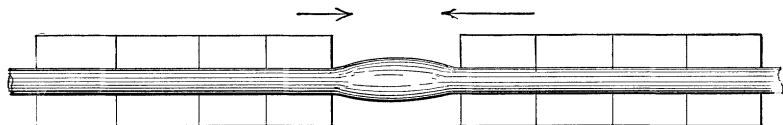


FIG. 4.

an end pressure on a bar which may be very long—100 or 200 feet, or more than that—or even a very long coil, so that we have to get whatever hold we can by hydraulic pressure applied laterally, and risk any deformation that takes place. [Applause.]

THE CHAIRMAN:—The electrical engineers have had to meet from their brother engineers in the development of the various stages in the department of electricity, a good deal of opposition and cynicism. The gas engineers we have had to meet with the development of the electric light. In the transmission of power we have had to meet the mechanical and civil engineers. Those two departments of electricity have been pretty well established and our brother engineers have been converted. But to-day, to use an expression of Prof. Thomson, there is a considerable amount of self-induction present in the minds of civil and mechanical engineers on the subject of electric welding. We would like to have a good many of them here this afternoon and show them some of the practical evidences of the commercial state of the art as it is to-day. This is an important paper. It is one which should attract and will attract a good deal of attention. There are gentlemen here with us who can give us further information on this subject, who we should be very glad indeed to hear from.

MR. WM. MAVER, JR.:—With regard to the causes that led to the objections to the burr left by the electric weld in the case of the telegraph wire, and without knowing the exact cause in the case in point, I would suggest that it may have been due to the fact that the presence of the burr prevented the free working of the wire in the act of stringing on the poles. In the case of hard drawn copper wire, this was one reason that led the companies to forbid the use of any "splices" in the coil. Another reason was that factory "splices" were found to conduce to breaks in actual service. Still another objection to a certain form of sleeve joint was that it facilitated permanent crosses between wires that otherwise would only have been swinging crosses.

MR. LOCKWOOD:—In common with the remaining portion of the audience, I have been particularly interested in this subject. I have watched it with great interest from the moment it was put before the public and before the profession. But this is the first time I have ever had an opportunity of hearing a paper read upon it or of hearing any discussion. I have always been so unfortunate as either to be absent from the country or otherwise engaged when the matter has been under consideration. It often occurs, I find, that different paragraphs in a paper of this character will impress different minds in a different way, and the paragraph which made the most impression upon my mind was that in which the union of two pieces of gutta percha was referred to. I find that this paragraph reads:

"Welding, in the ordinary sense, on an anvil, by means of a forge, is essentially the uniting of two surfaces of a metal which has previously been rendered plastic and which, under the hammer, can be made to intermingle into a structure similar or identical to the original metal. In consequence this can only be accomplished with materials capable of passing into a plastic state

before actual melting takes place. One of the most familiar examples of this weld to electrical men, is the common splice in the gutta percha core of a submarine cable."

It goes on to say: "Provided only that the surfaces are clean, it is possible to make this material unite as perfectly as before it was cut. Amorphous waxes and similar substances can be treated by a like method, but when we reach truly crystalline materials it is no longer possible to effect this union below the melting point, unless great pressures are applied."

Well, Mr. Chairman, in one period of my checkered career I was engaged in making plate glass. It is rather difficult for me to decide under which of these classifications glass comes. Whether it is a material that passes into a plastic state before melting takes place or whether it is amorphous wax or similar substance or whether it is a truly crystalline material. I have seen it in conditions which approximated to either one of those conditions. It certainly does before it melts, become plastic. I would like to ask whether the gentleman who wrote this paper and who has read this paper, can tell us whether anything has been done in working glass by electricity and whether that has come within the realm of his operations, or whether it is likely to. It is very difficult, of course, to imagine how you can get glass to be acted on by electricity, but there are so many things done by electricity nowadays and so many more things claimed to be done that I should not be surprised if that comes in one or the other category.

THE CHAIRMAN:—Perhaps Prof. Thomson has had some experience in this direction.

PROF. THOMSON:—The only experiment that I can recall at this moment is this: A tube of glass slipped over a platinum wire with current, and the glass heated by the wire so that the glass came down and stuck to the wire. But in the ordinary operations of the work of incandescent lamps, glass is sometimes rendered plastic, as we are quite well aware, and sometimes the heat from the filament or the filament itself touching the side of the glass softens it and the glass bulges in and makes holes. That, I think, must be taken as an instance in which electricity has got something to do with *working glass the wrong way*.

MR. LOCKWOOD:—In New Albany, Ind., in the year 1869, while working at a window and plate glass works, I found that the only way known at that time practiced of cutting off the end of the cylinders which were first blown and which were to eventuate in window glass, was to take a portion of glass from the pot on the end of a blow-pipe or pincers and twist it around the end of the cylinder for a moment, and then take it off and drop a little water on the place where the melted glass had been, and the end of the cylinder would then crack off at once. The cylinders were then placed in the flattening oven. Before placing them in the oven though, they were run with a red hot bar lengthwise. Then

they were placed in the oven and when they became plastic were flattened. Prior to that time my electrical knowledge had been gleaned by telegraphing. Nearly every young man at that time, who was engaged in the telegraph business, had at least invented a button repeater, and when I left the business temporarily I did not give up my interest in electrical work. Thus while watching the men taking the ends off these cylinders the way they did, it struck me that a fine wire, if heated by the passing of an electrical current, might be used to take off the ends of the cylinders, and I invested all my spare cash in a battery, and I got enough current to make an iron wire red hot. It worked like a charm. The glass blowers at that moment looked upon me as being something of a medicine man. After doing it two or three times, however, I found that my means at that time would not enable me to keep it up, although the thing was done and done well. I speak of it at this moment simply to show that there was an application of electricity to the manipulation of glass, and I may further say that within the last decade some fellow has patented that process.

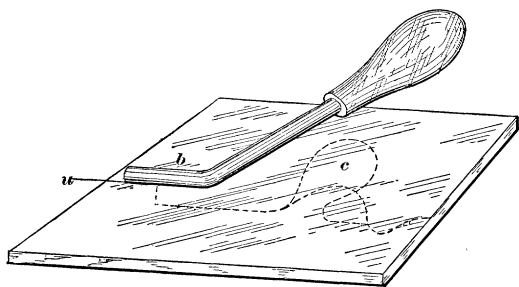


FIG. 5.

PROF. THOMSON:—Mr. Lockwood's remarks do recall another instance of a somewhat similar character. I can illustrate it better by going to the board. It depends on the fact of glass *not* being a material which can be made plastic at ordinary temperatures. Perhaps it is in relation to its being a brittle or crystalline material. You are all familiar, no doubt, with the fact that an iron bar can be used to cut glass, whether it be a cylinder or flat plate—that you can heat a piece of iron red hot and apply it to a glass plate in a proper way and lead a crack all over the glass as desired. Say this is a piece of window glass. You take an iron bar at a low red heat, having filed a notch, *n*, in the edge of the glass plate. [Fig. 5.] Now you take the iron and put it about $\frac{1}{4}$ inch away from the notch *n*, resting it on the plate. It is generally best to have the iron bent up a little and the part *b* red hot. You put it near the notch red hot, say there. The crack starts for the iron and stops there. You keep moving the iron ahead and you can cut the glass

into any shape you want, leading the crack all around in curves or in any other way; but you must be careful of one thing — never to return on your tracks and try to cut as at *c*, or it will break the plate irregularly. Now, it occurred to me that this operation could be much more easily done electrically, and so I constructed an arrangement for heating a small short wire and I arranged a corresponding wire on the other side of the glass, on the principle that it is best to heat the glass on both sides and so obtain much greater certainty of the result, and I found that with such a tool I could cut very thick glass with perfect certainty by using the heated wires both on the under and upper sides of the glass. The glass would split and follow the tool, the crack was also started very readily. Another thing developed at that same time. I found that I could cut a beveled edge on glass by setting this tool or wire which made contact on the upper side, at a point offset from that on the other side, and the crack would join the two. I could cut beveled discs in that way. The bevel was not perfectly smooth or regular, but was improved by simply grinding it a little.

THE CHAIRMAN :—The hour is growing late, and if there are any further remarks on this paper we would like to hear them. If not, I would like to call special attention to the evening session. There will be a paper read by Mr. Nikola Tesla, in Prof. Dwight's room at Columbia College, this evening at 8.30 p. m. The subject of this paper will be "Experiments with Alternating Currents of High Frequency." Many of those experiments have been produced before some of the gentlemen who are here at the present time, and they are of an exceedingly interesting character, and it is hoped that every one who is here now will be present at that lecture to-night. In the absence of the President, Prof. Bell, Mr. Lockwood will occupy the Chair.

The meeting then adjourned until 8.30 p. m.