Up a steep winding stair, a minute later we emerge from the semi-darkness into the bewildering light of the lantern room. Being politely offered a pair of black spectacles, we proceed a few feet higher up an iron ladder to a small gallery surrounding the slowly revolving polygonal structure of glass by which the light is caught up from the electric lamp within and refracted into the sixteen radial beams which form the distinguishing feature of this latest achievement of optical science by that eminent firm of lighthouse engineers, Messrs. Chance Brothers, of Birmingham. Through two thicknesses of darkened glass we venture a momentary peep at the central source of light itself—the tiny point, no bigger than a marble—where, with a loud hissing sound, a fierce combustion, and the light of 60,000 candles, the electric arc itself bridges the $\frac{1}{2}$ in. or so of interval which separates the incandescent carbon points. Some idea of the power of this light will be conveyed to the reader when we say that the carbon pencils, employed in the electric arc lamps commonly used for street lighting are about $\frac{3}{8}$ in. in thickness, while those at which we are now painfully gazing have a diameter of 60 mm., or nearly $2\frac{1}{2}$ in.

The lamp is of the modified Serrin-Berjot type, and the carbons, which are controlled by a duplex arrangement of spring and current, are not circular in section, but fluted, a valuable improvement introduced by Sir James Douglass, whereby the centrality of the arc is greatly promoted, the carbons are kept cooler, and a better supply of air to the lamp afforded. The sixteen-paneled dioptric apparatus is rotated, not by clockwork, as usual, but by a tiny vertical engine worked by compressed air from below. As the time of rotation is of the utmost importance, a most ingenious regulator or governor is applied to the little engine, which controls the speed by the automatic application of a brake should the motion become too rapid. But we must take our leave of this most interesting apparatus, and descend to the basement, where the steam engines, dynamos, and air compressors are at work.

Entering the engine room, a handsome building to the right of the tower, we see before us a row of three compound engines and boilers, each of 12 nominal horse power, but capable, as we are informed, of working up to 48 horse power should occasion require. These highly finished engines have been made for the Trinity House by Messrs. Robey & Co., of Lincoln, and embody the latest improvements of that celebrated firm of engineers. The fuel used is gas coke, the residue from the manufacture of coal gas, coal being thus utilized a second time in the production of an illuminant. All the three engines were in steam at the time of our visit, although only one was actually in motion, engaged in driving one of the large dynamos which generate the electric current. The ease and smoothness with which this Robey engine was working was really remarkable—when running at 172 revolutions per minute scarcely a sound was perceptible in the engine room. Ready for instant use, with fire banked up and steam at 150 lb. pressure, the second engine stood attached to a duplicate dynamo, only needing the movement of a lever to start into motion, in case of accident to the first set of machinery. The primary duty of the third engine is to compress air for the siren or fog horn. Air compressors are, however, attached to all three engines for use in cases of emergency, and huge reservoirs are constantly kept charged with air at 200 lb. pressure per square inch, so that the warning note can be sounded at any moment, night or day, when necessity arises.

The two dynamos are by De Meritens, of Paris, and if both worked in conjunction, it is computed that the concentrated light from the lantern would equal six millions of candles. The induction arrangement of each machine consists of sixty permanent magnets, and each magnet is made up of eight steel plates. The armature, 2 ft. 6 in. in diameter, is composed of five rings with twenty-four bobbins in each, arranged in groups of four in tension and six in quantity.

Throughout the installation everything is duplicated, and sometimes triplicated, to guard against the possibility of the extinction of the light even for a moment; and the order, regularity, and method by which the duties of each man and each machine upon the establishment are allotted and fulfilled is exactly what one would expect from the Trinity Board, whose motto seems to be, "Without haste, without delay, and the best of everything."

The whole of the new works have been devised and originated by Sir James N. Douglass, the engineer in chief to the Trinity House, and carried out under the immediate superintendence of his assistants, Mr. Ayres and Mr. Matthews, while the completed arrangements have been put under the charge of Mr. H. C. Millet—late engineer, R. N.—who for the last seventeen years has had similar charge of the electric lighthouse at Souter Point, on the Durham coast. In concluding this notice it is our pleasant duty to express our thanks to the Trinity House for the opportunity of being present at the official trial of the most powerful electric light in the world at St. Catherine's Lighthouse, on the 1st of May, 1888.—*The Engineer*.

PRACTICAL APPLICATIONS OF ELECTRIC WELDING.*

By O. K. STEWART.

THE history of electric welding extends over a much longer period of time than is generally supposed. Some eleven years ago, Prof. Elihu Thomson, who then held the chair of Chemistry and Mechanics at the Philadelphia Central High School, was delivering a course of lectures before the Franklin Institute of that city, and among other experiments by which he intended to prove the substantially identical nature of electrical energy under any and all circumstances, he reversed an ordinary Ruhmkorf induction coil, showing thereby the difference of potential between the current in the primary and that in the secondary of the coil. In performing this experiment he brought the terminals of the coarse secondary winding of the coil into contact, and was surprised to notice that a high degree of temperature was reached instantaneously at the point of contact, in fact, such a high degree of heat that the ends were stuck quite firmly together, the copper wire being actually melted, so that

it required considerable force to separate them. Instantly the thought flashed through his brain, electric welding.

Professor Thomson was, however, very busily engaged in teaching and lecturing, and in developing the Thomson-Houston system of electric lighting for the next five or six years, and it was not until, in the regular course of manufacturing electric lighting apparatus, it became an imperative necessity to discover some means of having more perfect joints in copper wire than could then be obtained that his mind reverted again to the old experiment at the Franklin Institute, and electric welding became an assured art.

I should like further to call your attention to the fact that the discovery was made several years prior to the building of a welding machine. Several years ago, I do not remember the exact date, the necessity for welding the ends of copper wires became so imperative that Professor Thomson designed and built a small machine with which to weld fine wires. The experiments with this apparatus were so very successful that the inventor decided to build larger and better apparatus and experiment further with a view to welding, if possible, much larger pieces of metal. These experiments were also successful, and the invention has been much further developed in the past year or two than the general public can have any possible idea of.

The theory underlying or the principle involved in the Thomson process of electric welding is very simple, as indeed is most of the apparatus also. The Thomson process of electric welding consists simply in forcing through the pieces of metal to be welded currents of such large volume that these pieces can carry them without heating. Now, when the pieces are placed in abutment, the point of greatest resistance, as you all know, is where they contact with each other, and it is of course at this point that the heat is first generated. The instant heat is generated at the point of contact, the resistance at that place enormously increases and a consequent more rapid development of heat is the immediate result. The metals are consequently raised to a high welding temperature in a very remarkably short space of time, and upon a slight pressure being applied to force the pieces together, a perfect welding is effected.

The field that is open for the process of electric welding is surprisingly vast, and of course no one can tell where it will lead to. I think the most important reason why electric welding is taking its place so rapidly—no, I will not say most important, but one of the most important reasons why electric welding is taking an important place so rapidly—is that the heat generated by the current is the only absolutely pure heat known in the world. The blacksmith, when welding with either a gas furnace or a coal fire, is constantly running the risk not only of burning his metal, but of introducing into it foreign matter in the form of gases which are very deleterious to the substances of either iron or steel, which are the principal metals worked by blacksmiths.

Now, the heat generated by the electric current is absolutely free from all foreign and harmful substances, and it is this fact, I think, which very largely accounts for the rapid advance of electric welding, so far as practical work is concerned. Of course, this is not the only reason. One very important reason is the fact that the heat effected by the current is under absolutely perfect control. Now, I do not mean to say that this regulation is nearly perfect, or that it is very perfect, but I state that it is absolutely perfect, for the reason that it can be made entirely and perfectly automatic. The heat can be begun, and a stop placed on the apparatus which will control the heat perfectly.

Then again, welding by the Thomson process is a much neater and quicker operation than welding by the ordinary method of forge or furnace. I might also say in this connection that no skilled labor is necessary to operate an electric welding apparatus. I have in my mind now one young man who came to us not knowing anything of the conditions under which different metals should be welded, and who in a very short time has become so expert in handling these machines that he can now, on the first trial, make perfect welds in any of the ordinary metals and in almost all varieties of steel, including, although I say it with some reservation, even Mushet steel and manganese steel.

As I have already stated, the field for electric welding is so very broad that I have been really much embarrassed in endeavoring to present the most interesting portions of it to you this evening. There are hundreds of applications of the process, and under the circumstances I do not think I can do better than simply cite one or two instances or examples of very small work, and then some of larger work. We are not limited of course in our work by the size of the pieces to be welded. We can weld the finest wires and the heaviest pieces. As an example of quite small, though not the smallest, work, I might mention the welding of gold rings. We have succeeded in welding gold rings. I want to call your attention to the fact that I say we have succeeded, you understand, have. It is no longer a matter of experiment, but the welding of gold rings by our process is an assured success. Now, what does this mean? It means, first, that we can make a better joint than is now made, doing away entirely with soldering, and in its place making a continuous gold ring; secondly, it means that the work is accomplished in about one-fifth of the time that it now takes to make a decent joint; and it means, lastly, that soldering material is saved, that an enormous wasting of heat is done away with, and that the dangers of burning gas are entirely obviated.

As an example of somewhat larger work, I might mention the welding of axes. There is, not very far from Boston, a manufacturing establishment which turns out about three thousand axes a day. Their ax is made of a body of ordinary wrought iron, to which is welded an edge or face of fine tool steel, tempered and toughened. Their pieces of metal, before welding, have to be prepared somewhat in this manner. That is, a groove is cut in the body of the ax, while a taper is cut on the face or blade, the latter being set into the former and the pieces welded in this position. (Blackboard illustrations.)

Now, in electric welding we do away entirely with this preparation, and I am very glad to say that without very much experimenting we have been able to entirely convert the engineer of this company to electric welding. He is now a firm believer that electric welding is the thing so far as the ax business is concerned.

As an example of much larger work, I might mention the welding of pedestals and locomotive frames. This is an entirely different class of work. The pieces have to be carefully prepared like this (blackboard illustrations), a raised portion being left on the base or edge of the frame, and a taper groove being cut in the pedestal so that it may fit down over the raised portion referred to.

Some months ago I had the pleasure of being in Philadelphia, and while there of walking through the Baldwin Locomotive Works. This establishment is turning out fourteen locomotives a week. Now, what does this mean for electric welding? In the first place, on these engines there are some five or six copper rings, the wire composing which is of small diameter. The joints in these rings are at present made with a blow-pipe flame, and it takes an expert some four or five minutes to make a single one. We can make them in as many seconds. There are also on each one of these locomotives at least one hundred and fifty joints in iron, from a half inch area of section to several inches area. Now, it takes anywhere from four to fifteen minutes to make these joints by the ordinary process, and welding, you must remember, has been reduced to a very economical and accurate art in this establishment, but nevertheless we can do the work in at least one-fifth of the time which they now occupy. There are on each one of these locomotives four frames, each frame having on it at least two, sometimes three, four, and five pedestals. We will suppose that the average is three pedestals per frame. That makes twelve pedestals to the locomotive. To prepare the ends of the pedestals and the taper on the base of the frame takes some forty minutes. They have to be heated and hammered into shape while hot. After they are prepared in this manner (blackboard illustrations), they have to be reheated to a welding temperature, placed under a steam hammer and welded, this last operation requiring some thirty or forty minutes. You can easily see what this means. We allow twelve joints to each locomotive, and this makes one hundred and sixty-eight pedestal welds a week—one hundred and sixty-eight welds, understand me, which require at least one hour's time each.

In talking the matter over with Mr. Converse, who is the general manager of the company, I think we came to the conclusion that we could "beat this all hollow," the only question in the mind of Mr. Converse being whether the weld would be as perfect as at present. You will see that we would do away entirely with the preparation of the pieces, making a butt weld of the pedestal to the bit or expansion on the base.

There are, of course, a large number of other applications, but I think that these three should be sufficient to indicate at least what the possibilities of electric welding are.

There is one thing that I should like to mention finally, that we are able to make very durable, strong joints between metals of different kinds. For instance, these specimens which I hold in my hand consist of brass and copper welded together, and then twisted around twice. The joint held through this twisting, showing the strength. You will see that it is not even cracked.

What do we expect in the future for electric welding? We expect to be able to weld boiler plates. We do not say that we are able to do it now, but we have been thinking over the matter and experimenting, and we believe that this welding of boiler plates together is a thing of the not distant future. The same may be said of any metal plates.

We expect also to be able to weld tubes in the length. I do not wish to be misunderstood. I do not say that we are now able to do this, but I do say that we believe it can be done.

We are at present working upon apparatus of a light, movable character, which, without mechanical power, we believe will be powerful enough to weld line wire, such as telephone, telegraph, and electric light and power wires on the line. The apparatus can be put into a wagon and carried to any desirable point. The current obtained from storage batteries forms a portion of the apparatus, and the welding is effected on the line.

We expect also to weld lead pipe in the same manner, so that any plumber can have a welding apparatus with which he can make one continuous lead pipe in mending and in building, doing away entirely with "wipe joints," and the expense attendant thereon.

With an absolutely pure heat, with absolutely perfect means of regulation, with the heating constantly before the eyes of the operator, with a neatness to which ordinary methods cannot at all be compared, with an increased economy of, in all ordinary cases, at least 300 per cent., with absolute safety of handling apparatus—with all these advantages, I do not see why electric welding should not rapidly rise to the dignity of a most important and valuable art. I can only say in conclusion that I shall be glad to answer any questions that I can answer and which may be asked.

IMPROVED ALTERNATE CURRENT DYNAMO.

THE alternate current dynamo which we illustrate opposite is the invention of Mr. W. M. Mordey, and is being brought out by the Anglo-American Brush Electric Light Corporation, London. It is a wide departure from the usual form of alternate current machine, and presents several features of great interest. The armature coils are stationary, while the field magnets revolve. This, of itself, is not new, but the idea is carried out in this machine in a perfectly original manner. The coils are quite thin, and stand between the poles of a revolving magnet, the space separating the poles being very short, and consequently forming a very intense field, which is almost filled with the coils. All the magnet poles on one side of the coils are of one sign (say north), and all the poles on the other side of the opposite sign (south). This is contrary to the usual practice, in which north and south poles occur alternately. It follows from this arrangement that the polarity in the coils is not reversed as the magnets revolve, but instead it rises from zero to the maximum, and then falls to zero again, and so on. The magnetization of the coils is always of the same character; it merely varies in intensity. This variation is as great as in the old machines, because the field is so much stronger. Formerly, when north and south poles occurred in the magnet, side by side,

* An address recently delivered before the Boston Electric Club.