

PRACTICAL ASPECTS OF THE ALTERNATING CURRENT THEORY.

DISCUSSION OF DR. M. I. PUPIN'S PAPER AT THE GENERAL MEETING, BOSTON, MAY 21, 1890.

(See page 204 *ante*.)

THE PRESIDENT :—We would be glad to hear any remarks now upon this very interesting paper.

MR. CROSBY :—I would like to ask whether Dr. Pupin finds that it is really a simple matter to design an alternating motor as compared with the work of designing a continuous current machine. While the general theory may be expressed with almost equal simplicity, will not the introduction of those mathematics, the value of self and mutual induction, make it a more difficult matter to design an alternating than a continuous current machine?

DR. PUPIN :—Well, not being a practical man and never having designed an alternating current machine or a continuous current machine, I, of course, could not answer that question.

PROF. THOMSON :—I should say that having designed both continuous and alternating machines, I see no particular difficulty in doing either; there are certain things that are left out altogether in the design of alternators which have to be considered in the designing of continuous current machines, as in the commutation. Of course the simplest forms of expression will not take in all the little attentions that have to be given in that direction. So it is with the alternator we may say that there are some things to be attended to which are not taken in in the simplest forms of expression, but so far as I can see I should say that the problem is not more complex than that of designing a good continuous current machine.

THE PRESIDENT :—I understand that the experiments which are to be taken up in the next paper require the use of the steam engine and that steam is being kept up for us, and I think we had better pass on to the next paper and resume this discussion later. There will be an opportunity for continuing this discussion after the reading of the paper by Mr. Lemp on automatic electric welding machines.

AUTOMATIC ELECTRIC WELDING MACHINES.

BY HERMANN LEMP, JR.

AMONG the latest achievements in electrotechnics, stands prominently Prof. Thomson's electric welding process. The broad underlying principle has so often been described and exhibited by its able discoverer and others, that to repeat it now would be imposing upon your patience. The evolution of a new process and its reduction to practice for commercial purposes, especially if the leading elements of its working are novel in themselves, must necessarily open a vast field for investigation. Such is the case with electric welding, and with a view of showing the commercial apparatus of to-day, it will be necessary for me to state the electrical and mechanical requirements which led to its construction.

The reason for which machines have been invented has been for the purpose of reproducing faithfully and constantly a set of conditions necessary to obtain a certain result. When the conditions in any case are few and the product simple, generally one design of machine will be sufficient. With an increased number of conditions, however, the complexity of the apparatus increases rapidly and demands, in many cases, a subdivision into different processes to be executed by separate machinery. What constitutes skill in a workman, for instance, is the ability to coordinately reproduce a number of operations or movements; to be, in other words, a perfect machine, or to produce the same result even if other conditions than those previously contemplated should arise.

To secure uniform results in the practice of a difficult operation, there are two ways possible.

1. To employ skilled help for the complex portion of the work alone.

2. To substitute for the more complex portion of the operation one more readily controlled.

The ordinary welding process requires the greatest skill at the hands of the blacksmith for heating the metals to the proper temperature and at the right spot, while preventing the accumulation of cinder or scale. While skill may be successful with metals of high melting points and low conductivity for heat, easily fusible metals and specially good conductors baffle all attempts as long as an exterior heating source is employed.

The electric welding process has, as you know, not only made it possible that operators not particularly skilled in the art of blacksmithing can produce good substantial welds, but has created an art equally adaptable to all metals and combinations of metals.

The following are all the metals, alloys and combinations so far actually welded with success by the Thomson process ;

Metals.—Wrought iron, cast copper, antimony, aluminum, manganese, cast iron, lead, cobalt, silver, magnesium, malleable iron, tin, nickel, platinum, wrought copper, zinc, bismuth, gold (pure).

Alloys.—Various grades of tool steel, various grades of mild steel, steel castings, chrome steel, musshet steel, stub steel, crescent steel, bessemer steel, cast brass, gun metal, brass composition, fuse metal, type metal, solder metal, german silver, aluminum alloyed with iron, aluminum brass, aluminum bronze, phosphor bronze, silicon bronze, coin silver, various grades of gold.

Combinations.—Copper to brass, copper to wrought iron, copper to german silver, copper to gold, copper to silver, brass to wrought iron, brass to cast iron, tin to zinc, tin to brass, brass to german silver, brass to tin, brass to mild steel, wrought iron to cast iron, wrought iron to cast steel, wrought iron to mild steel, wrought iron to tool steel, gold to german silver, gold to silver, gold to platinum, silver to platinum, wrought iron to musshet steel, wrought iron to stub steel, wrought iron to crescent steel, wrought iron to cast brass, wrought iron to german silver, wrought iron to nickel, tin to lead.

But Prof. Thomson was not satisfied with this progress made above ordinary welding, and early recognized the importance of a machine in which all conditions for successful operations are mechanically controlled to produce uniform results, and which would be rapid working and require little or no attendance.

Such machines now known as automatic welding machines, have proved to be of special importance in connection with easily fusible metals, enabling the successful welding of aluminum, silicon and aluminum bronze, which, even with the electric process, require considerable skill.

Before entering into a detailed description of the automatic welder, a few general data on welding will be in order.

The Thomson process of electric welding can be, and has been, worked by means of continuous or alternating currents; secondary batteries or multipolar machines may be and have been used. There are such conditions as transportability, absence of motive power, situation in continuous distribution district, etc., which may make it advisable to use the continuous current. The alternating currents have so far been the best adapted to be produced economically of large volume at low E. M. F. They are easily and economically controlled, allow of being distributed at high pressure with small conductors and of being reduced to working pressure wherever needed. They have, however, another beneficial effect, which is of importance in all welds of large sections.

It is a well-known fact amongst manufacturers of incandescent lamp filaments of large section that the inner portion in a filament is apt to be overheated. In treating filaments as used in the now commercial series lamp, in a hydro-carbon atmosphere, the writer attempted at one time to produce an extra good quality of carbon by starting with an extremely thin base .004 inch thick and obtaining a filament, 90 to 95 per cent. of which consisted of hard, gray, lustrous carbon. He thought to extend this process to the manufacture of arc light carbons and even produce pencils of about $\frac{1}{4}$ inch diameter. What was his surprise, however, to find that although the lustrous surface presented at times a dense gray structure, the core lost this character after a certain thickness of carbon had been deposited. In fact, a number of concentric layers could be discovered from the innermost graphite to the dense gray semi-crystalline at the outside.

This action can, to my mind, only be attributed to the overheating of the carbon particles in the inside. A similar action takes place in a bar of iron if heated by an electric current. The surface exposed to radiation will be at a lower temperature than the core. It is true that the heating of the metal will increase its resistance and thus tend to equalize the temperature, but not enough in all cases. By the use of alternating currents we gain, however,

an assistance in the self-induction. The effect of the latter is especially marked and has a tendency to concentrate the heat on the surface.

If there is any place which receives more current than another the effect of the self-induction is emphasized by the fact that the surrounding part is cool and its permeability is greater than the part traversed by the surplus of current. With very large, and especially wide, metal pieces the unevenness of distribution may be remedied by approaching iron masses to create at a given spot a greater self-induction or counter E. M. F., thus diverting the current from that section. Prof. Thomson has early recognized the importance of, and patented, a device to prevent the heating of the metal at a given spot by creating locally increased self-induction or magnetic effects.

In view of this experiment almost daily witnessed by us, it is interesting to note the paper controversy between parties disputing the priority of a device which is to produce exactly the opposite result with, however, the same means and conditions.

Two methods of distribution are in use, the direct and the indirect. In the former, an alternating current dynamo is used, having two windings on the armature, one of which furnishes currents rendered continuous by a commutator to excite the field magnets, and is controlled by switch and rheostat; the other consisting of a single turn of heavy copper cable furnishes the welding currents, which is led through collector and brushes to movable copper clamps suitable to receive and guide the welding specimens during the operation.

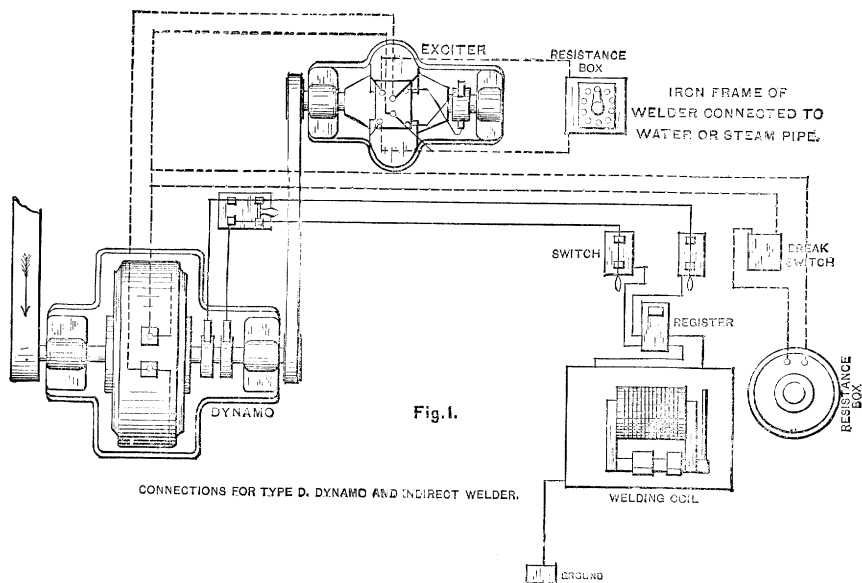
In some other forms the field magnet is the movable part, in which case no heavy currents have to be carried through collector and brushes. No direct welders are built at present for currents larger than 4,000 amperes.

The indirect method of distribution is almost exclusively used to-day. It consists in its simplest form of one alternating current dynamo, self or separately excited, and one welder which is a transformer with the necessary clamping and operating appliances. The self-exciting dynamos used are from 1,000 to 20,000 watts output, and may be regulated by means of a reactive coil to give a varying E. M. F. never exceeding 300 volts.

They are substantially built to withstand sudden strains. have self-oiling bearings; the brushes are designed never to be moved

and are perfectly sparkless, requiring no other attention than cleanliness.

The winding on the transformer being set once for all, variation in the E. M. F. has to be obtained either by varying by hand the initial E. M. F. of the dynamo or by exciting a dynamo to the lowest potential required, it being so compounded as to give with the maximum work the increased E. M. F.; or finally to maintain a constant E. M. F. at the dynamo under all loads and vary the E. M. F. at the transformer by interposing a variable resistance, or preferably a self-inductive resistance. The transformer itself may be built so as to give a different ratio of conversion, either



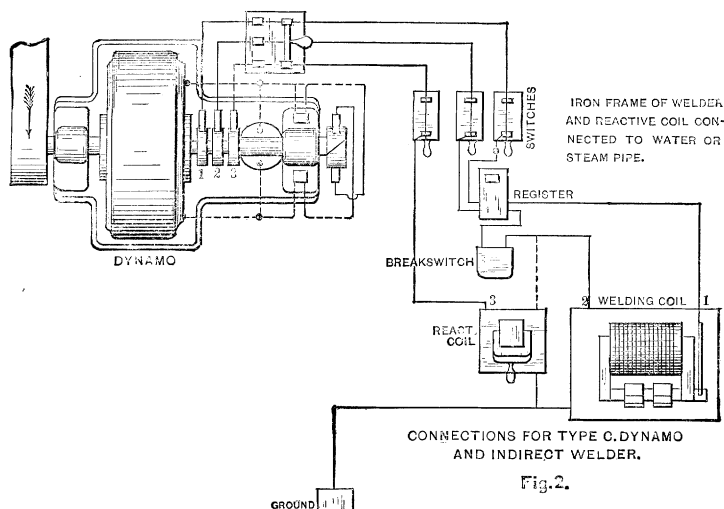
by moving the primary and secondary relatively to each other or by shunting lines of force by means of an iron bridge between primary and secondary, or by altering the number of turns in primary or secondary by a switch.

When a single plant is used, viz., one dynamo and one welder it is the dynamo, generally, which, if separately excited, is regulated by means of a rheostat in the exciter circuit, or by a reactive coil in series with the exciting coil on the armature if self-excited. The diagram, Fig. 1, shows the connections used with a separately excited machine. The only thing different from similar installations is the break switch which is operated by a foot

treadle and automatically opens the circuit when the foot pressure is removed.

This prevents any mishaps when operated by uninitiated persons, as all action ceases when one leaves the apparatus. The primary voltage never exceeds 300 volts with 100 alternations, or 50 complete cycles per second. Nothing but the very best insulation is used in the primary wiring. It is deemed necessary to protect users of the apparatus not only against any shocks, but even against the scare of one, and we recommend the permanent grounding of the secondary which in welding apparatus is virtually the table and pressure devices.

Fig. 2 shows the connections used for a self-excited composite



dynamo, which has two windings on the armature, a longer main and shorter exciting coil. Both are wound in the same direction, and currents generated therein pass in multiple, connected through the shunted field magnet; after this through line No. 2, controlled by a break switch, and then split, one returning through reactive coil and line 3, the other through welder and line 1 to their respective windings. The exciting effects of each circuit add themselves. The reactive coil is conveniently placed near the welder. Dynamo is regulated from the minimum to 300 volts and is excited anew for each weld.

For some work which requires to be done at great speed, the second method is resorted to; that is, to keep the field con-

stantly excited by fixing a variable reactive coil in a given position, just enough to produce about 150 volts, the lowest E. M. F. required. The proportion of the field magnets, the E. M. F. of exciting coil and the resistance of a shunt to the field are such as to produce an overcompounding of 100 per cent. in this case, with the largest current in the primary.

This method of regulation is very neat, as it is absolutely automatic, responds quickly, the field of the dynamo not requiring to "build" every time from residual magnetism alone. We sometimes call it "cubic compounding," as it produces a constant heating effect for variable cross sections and variable lengths as well. With this modification, the wiring of diagram, Fig. 4, is slightly altered, the break switch breaking only the main circuit, leaving the exciting circuit permanently closed.

The methods so far described are only used when a single welding machine is to be operated. It was early recognized that if the process is at all to be used on a commercial basis, the generating of the necessary current at least should be limited to as few machines as possible. It required, in other words, a dynamo giving a nearly constant E. M. F. of sufficient capacity to feed a number of welders while maintaining for each absolute independence.

Since all welding for a long while to come will probably be operated in isolated plants, the dynamo is to be placed in the hands of an engineer, generally not an expert in electrical matters, and has, therefore, to be easily attended and free from all the little faults and kinks which are at present the sole consolation of the dynamo tender. One of its prime requirements is close automatic regulation under all loads.

Constant potential, self-regulating dynamos are manufactured in various sizes and are self-exciting up to 30,000 watts output. Dynamos with larger output are separately excited, but also self-regulating. The methods employed to obtain regulations are novel and will form the subject of another paper at some future date. I would simply state that either constant potential, or a percental increase with load can be obtained and that the regulation will respond even if the load consists of self inductive translating devices. I lay some stress on the regulation of the dynamo for the reason that the generators are not to be placed in the hands of special attendants as in case of a central station, but have to deliver their currents under constant pressure whatever

may be the conditions of work they are subjected to; even an automatic regulator would hardly be able to follow the rapid variation of load.

The following conditions influence the perfection of the work and are variable with different material and sizes :

1. Projection of the abutted pieces in the path of the current.
2. E. M. F. of welding current as controlling the strength of current flowing.
3. End pressure applied to force the abutting ends into each other at welding heat.
4. Interruption of current at proper time.

1. The projection of the abutted pieces varies with the diameter. It has been found that for copper, a projection for twice the diameter for each clamp gives the most economical results. With steel and iron, the most economical projection equals the diameter and is one and one-half times the latter for brass.

The projections sensibly affect the energy required and the most economical one depends upon the heat conducting properties and specific resistance of the specimens. Accordingly, highly conducting bodies require longer projections; highly resistant ones, short projections. Conductors of larger and smaller diameters may be welded by giving to each its respective projection. In the same manner wires of different materials may be joined to each other.

It is easily understood that since unequal projections on different sized conductors produce the proper heating of both at their junction, equal projection of equal sized conductors will be required. All other conditions aside, it is important to keep the projection for a given size and material constant.

2. The E. M. F. required depends upon the projection and the resistance of the material to be welded. For large cross sections the specific self-induction plays an important role, and indirectly, the shape of the specimen.

Another factor affecting the E. M. F. is the resistance between clamps and material and the resistance of copper conductors. The E. M. F. required for iron and steel is nearly double that for copper and would be four times if equal projection were used for both.

A certain drop of E. M. F. will be found from the clamps to the specimens. This drop is rather low on material having naturally bright surfaces, as, for instance, copper, brass, german silver, tin

or even cold rolled iron and steel. For a large class of work, however, especially in carriage hardware, the surfaces to be used for contact have a slight scale left after passing through the rolls, which has either to be removed by grinding or filing, or to be overcome by the E. M. F. of the current. In a good many cases the introduction of a special process of cleaning is deemed to be more expensive than to use a little extra power to work through the scale.

3. For uniformity of results the end pressure required to press the abutting specimens into each other at welding heat is of more importance than any of the former agencies; this is, in fact, the one which controls and rectifies any inaccuracies in the former conditions. If the pressure necessary for a given size and material is used, the weld cannot be performed until the metal has acquired the necessary plasticity to yield to the pressure. If for one reason or another, the E. M. F. and, consequently, the current should have been too strong, the time necessary for welding alone is affected, and in this case shortened. The bars will, however, be united at the same temperature and with the same force, whatever may have been the time required to bring about the necessary plasticity. The pressure will in some respects influence the heat by forcing the metals into each other at either higher or lower temperature, and by so doing cause the action to be interrupted at an earlier or later period as may be required.

The pressure required varies with the material and is approximately 1,800 lbs. per square inch for steel; 1,200 lbs. per square inch for iron; 600 lbs. per square inch for copper; it varies also with the area of cross-section as indicated by its being expressed in a function with the surface as one of the factors.

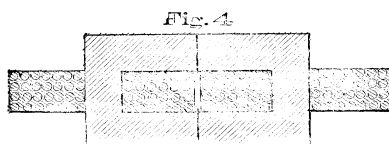
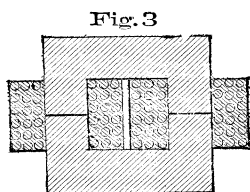
4. The interruption of the current as soon as the weld is completed is important for all easily fusible metals. When two copper wires are welded together the welded portion being increased in cross-section owing to the end pressure, if the current is not interrupted a large portion of the conductor on either side of the weld, including the latter, become heated and will melt and be torn asunder before any pressure device could follow and bridge the gap over.

The current should, therefore, be interrupted as soon as the weld is completed. It is also sometimes required that the parts to be welded should be of a certain predetermined length, in

which case the interruption of the current as soon as the allowable distance has been reached is essential.

All these conditions are maintained constant in the automatic welder before us, which is the first commercial type of its kind. This welder is not entirely automatic in the strict sense of the word. The degree of automatic action has to be considered separately for each individual object. This machine contains, however, the leading features as covered by Professor Thomson's patent, June 26, 1888, No. 385,022, with a few improvements in mechanical construction.

The capacity of the machine is, nominally, copper wire, No. 6 to No. 17 A. G. It will, however, weld larger and smaller sizes. It weighs 130 pounds complete; the secondary is one solid copper casting of a cross-section resembling a hollow, square box with one of the sides removed. This casting is firmly screwed to an iron table. A saw cut at right angles to the plane of loop creates the two poles, one insulated from the table, the

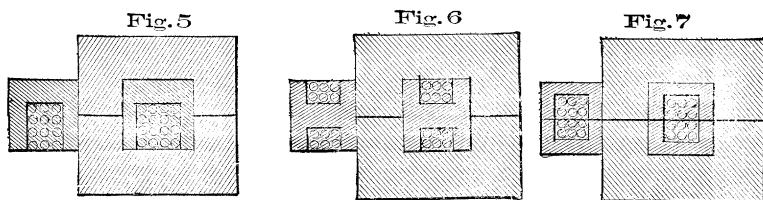


other constituting a V-shaped bearing suitable to receive a sliding clamping device. The hollow part of the secondary receives the primary coil which is separately wound in a form and insulated with special care. Two U shaped laminated iron cores embrace the primary and secondary.

It has been found that the best form of transformer is the one in which the primary and secondary coils are co-axially placed in an iron core, so as to oblige all lines of force generated by the former to cut through the latter. If the two windings are placed side by side on an iron core or on opposite legs, as shown in Fig. 3, there is a tendency to form consequent poles at the point where the two windings meet, due to the leakage of lines of force. The leakage will depend upon the distance between the two legs, and upon the length of the magnetic circuit. It has been purposely increased and turned to advantage by Prof. Thomson, for obtaining constant current in the secondary, while the primary is supplied with constant E. M. F., as shown in Fig.

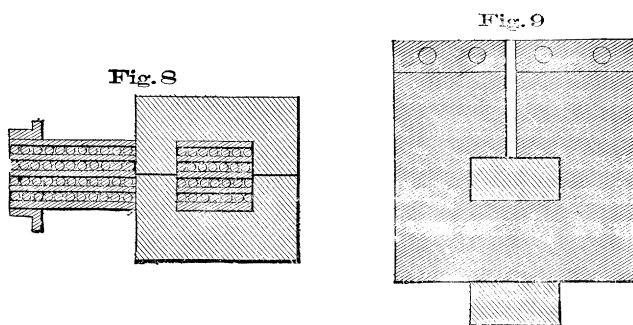
4. When, however, constant E. M. F. in the secondary is required, it is important that this leakage should be decreased to a minimum.

Various forms of secondary may be employed to work consistent with the above principle. A few of these are shown in diagrams Nos. 5, 6, 7 and 8, in which cases the secondary is preferably a solid copper casting. The forms shown in Figs. 8 and 9, however, permit hard rolled copper plates to be used.



For mechanical reasons and convenience, the forms shown in Figs. 5 and 6 are mostly used, and actual experience shows practically no leakage. This construction permits of removing the primary without disturbing the secondary in the least. It also gives the least possible self-induction for a given cross-section.

It is often stated that when large quantities of alternating cur-



rents have to be conveyed through copper conductors, it is important to have the same laminated or subdivided in smaller conductors to reduce self-induction. This may be true to a certain extent. The shape of the cross-section is, however, far more important than the lamination. An experimental compound conductor consisting of a number of flat copper ribbons in parallel showed a self-induction of *three* when the ribbons

were closely packed, of *two* when separated into two parts, and *one* when spread open like a fan. The explanation for this was given to the Institute last year by Prof. Thomson when he showed the self-induction to depend mostly upon the length of the lines of force surrounding a conductor when traversed by intermittent or alternating currents.

Returning to the subject before us we find that the pole which is insulated from the table constitutes the stationary clamp. The uninsulated pole, which is considerably larger, has on its upper side a long V-shaped groove parallel with the axis of the

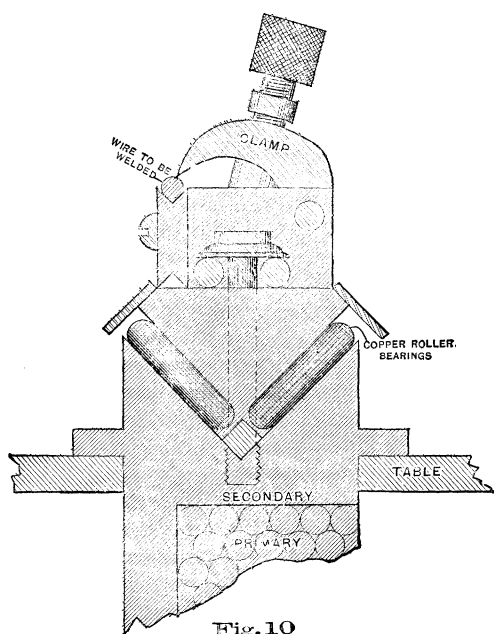


Fig. 10

secondary, Fig. 10. A movable copper block, also V-shaped, fits in the bearing and can be slid forwards and backwards in the same.

This movable block carries the second clamp. The current necessary for welding has to pass through this sliding contact. The welding of small copper wire or any other easily fusible metal, is a very difficult thing if special apparatus is not used. The current required is very large, several hundred amperes for wire not larger than No. 17 A. G.

The metal when it reaches welding heat readily melts away and

has to be followed by the movable clamp so as to prevent the breaking of the circuit. This latter action when it occurs, is so violent that a special device is necessary to prevent injury to the coil in case of such a rupture. The moving clamp, in order to follow the softening of the metal has therefore to have as little friction as possible and yet has to make a good contact to carry the heavy currents. The clamp is furthermore required to move in true guides so as to abut the small conductors with their axes in line. The heating necessarily brought about when rapid and continuous welding is done must not interfere with the bearing and cause the carriage to stick through expansion.

All these conditions have been complied with in using the V bearings, the carriage being held down in contact by means of a heavy spring and a number of copper rollers being interposed between the carriage and the bearing. Fig. 10. The copper rollers are simple short pieces of $\frac{1}{4}$ inch hard rolled copper wire rounded at the ends. There are sixteen altogether, eight towards the front and eight towards the back of carriage, equally distributed on both sides of the bearing.

A stationary rod at the apex of the bearing prevents the interference of the two rows of rollers. Between the two sets of rollers in front and in back, a bolt passes, applying the spring pressure which forces the carriage into contact with the bearing. A pressure of 40 pounds may be employed, and yet the carriage will move freely. These sixteen rollers have to transmit a current of approximately 3,000 amperes. They absorb about 20 per cent. of the total energy, which loss is, however, fully balanced by the reliability and simplicity of the device. This loss is moreover only on the maximum sizes and becomes insignificant on small work.

An adjustable coiled spring pulls the sliding clamp towards the stationary one. In front and pivoted on a lever is the distance gauge which may be inserted between the two clamps. This gauge carries on a central disk a number of steel pins of varying lengths, but equal projection on either side of the disk. These projections, if inserted between the two clamps, give the necessary distance required for a given size wire, the disk against which the wires are abutted insuring equal projection of both ends to be joined. On the back of the apparatus a switch is located in a primary circuit, which is normally held open by a spring. By moving the handle to the right, the primary will be

closed and the switch locked by a little catch underneath the table. A pin fastened to the movable clamp will lift the catch and release the switch, thus opening the circuit.

An intermediate lever between catch and pin operated by a sliding rule, which serves also as an index, permits of varying the point of cut-off, which has to be in a certain relation to the distance between the clamps. The position of cut-off, tension of spring, distance between clamps corresponding to each other, are marked with the same figure, which is also inscribed on a wire gauge fastened to the welder. By inserting a wire into the gauge, the number read will give the necessary adjustments at once.

If by imprudence, the switch should be moved to the right, while no stock is inserted and the clamps come in contact with each other, the switch cannot be locked and the fuse in the primary will be blown, without, however, causing any damage.

The insertion of the distance gauge between the clamps locks the switch so that the primary can only be closed after withdrawing the gauge.

The operation is as follows :

1. The wires to be welded are gauged.
2. The distance gauge and cut-off are set to correspond with the number on the gauge.
3. The movable clamp is moved to the right and the gauge inserted.
4. Both wires are securely clamped, care being taken to abut the ends squarely against the disk.
5. The gauge is withdrawn.
6. The switch is moved to the right.
7. The reactive coil is moved towards a position of minimum reaction, and restored to maximum after the weld has been completed.
8. The clamps are opened and the weld removed, after which the operation can be repeated.

If a good many welds of the same sized material are to be made, the reactive coil may once for all be set in a given position and the switch alone be operated. Welds made with the automatic machine have attained a uniformity not obtainable with the most skilled operators working without it. In fact, small, easily fusible wires can scarcely be welded with certainty with ordinary apparatus. For aluminum, especially, the automatic apparatus is needed.

The reactive device used in connection with welders is of the type recently described by Prof. Thomson, in which a case is made to more or less cover the primary, the self-induction of which is to be altered. To obtain a still larger range, the windings of the primary can be coupled in series, or multiple series, or in multiple by a switch in the base of the coil.

As mentioned before, the welding of easily fusible metals may sometimes cause a rupture of the secondary circuit, which, owing to its violence and volume of energy may cause a burn-out of the primary if not guarded against. This danger is not very great in the automatic machine, since the end pressure does not depend upon the attention of the operator. A special device is, however, used as an extra precaution against all emergencies.

Breaking a high tension circuit rapidly is not easily done. An arc generally follows the break, and this lengthens the time of the rupture. If the voltage of the circuit to be broken is so low that over the slightest distance an arc cannot follow, the break will be instantaneous. This is the case with the secondary circuit of a welding transformer. The voltage being ordinarily only one volt, even if increased ten-fold, would not be able to maintain an arc. However, multiplied in the primary it will cause E. M. F. sufficient to pierce through the insulation as ordinarily used. This action is similar to that of a Ruhmkorff coil in which the interrupter is caused to break under oil or water. This discharge is taken care of by a special apparatus, the description of which I reserve also for another communication to the Institute.

While the machine before us is only one type embodying the principal features contained in all, others have been manufactured or are in process of construction in which the automatic character has been carried out even further, as in the welding of rings and chains. I am not permitted to give a detailed account of these latter at the present time, but would say that the present model in its first form, is able to produce 250 feet of chain in a day without any attendance to speak of, the plain wire being fed into the machine at one end and the complete chain coming out at the other.

The automatic principle is, however, not confined to small conductors. We have welders with 40,000 watts output, capable of welding 1 inch copper or 2 inch iron, constructed and working

daily on that plan. The projections are determined by adjustable stops, the pressure, the most important of all, is hydraulic, and regulated by an automatic reducing valve, the exhaust being used for cooling the clamps at the same time. The primary is controlled by adjustable reactive coils from a constant potential circuit, and is interrupted at the proper time by the clamps. While not all machines are to-day operated on this plan, I am convinced that the evolution of the {welding process tends in that direction, and that the welding in future will be in the full sense of the word a purely mechanical operation. This cherished idea of Prof. Thomson's, uttered a few years ago, has well been borne out by the experience gained in actual operation on a commercial basis.

DISCUSSION.

PROF. THOMSON :—There is just one remark I would like to make, and that is, that Mr. Lemp is entirely too modest to put in any claims for his own work in relation to this matter. But I can say that he has worked diligently and faithfully in all the details of designing dynamos and proportioning the various arrangements, and has done a vast amount of very successful work, and I should like to testify to it here before the Institute.

THE PRESIDENT :—It seems necessary to postpone any further discussion of this paper at the moment, as there is here a paper by Mr. Lockwood which will be read by the Secretary.

Mr. T. D. Lockwood's paper on "The Industrial Utilization of the Counter Electromotive of Self-Induction" was then read. (*See page 226 ante.*)

THE SECRETARY :—Before closing, I move a vote of thanks to the authorities of the Massachusetts Institute of Technology for the many courtesies extended to us in providing facilities for the holding of our meeting in this city.

The motion was carried, and the meeting then adjourned.

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ELECTRICAL ENGINEER.....	"	"
L'ELETTRICITA.....	"	Milan, Italy.
EL TELEGRAFISTO ESPANOL.....	"	Madrid, Spain.
BULLETIN DE L'ELECTRICITE..	"	Paris.
ELECTRICITE	"	"
ELEKTROTECHNISCHE ZEITSCHRIFT.....	"	Berlin.
REVUE INTERNATIONALE DE L'ELECTRICITE..	Semi-Monthly..	Paris.
ZEITSCHRIFT FUR ELEKTROTECHNIC.....	Monthly	Vienna.
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ENGINEERING	"	"
INDUSTRIES....	"	"
JOURNAL OF THE SOCIETY OF ARTS.....	"	"
ENGLISH MECHANIC.....	"	"
SCIENTIFIC AMERICAN.....	"	New York.
RAILROAD GAZETTE	"	"
RAILWAY REVIEW.....	"	Chicago.
ENGINEERING NEWS....	"	New York.
ARCHITECTURE AND BUILDING.....	"	"
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PERIODICALS ON FILE—Continued.

AMERICAN ENGINEER.....	Weekly	Chicago.
MANUFACTURER'S GAZETTE.....	"	Boston.
INDUSTRIAL WORLD.....	"	Chicago.
AMERICAN GAS LIGHT JOURNAL.....	"	New York.
PROGRESSIVE AGE.....	Semi-Monthly..	"
LIGHT, HEAT AND POWER.....	Weekly	Philadelphia, Pa.
MECHANICAL NEWS....	Semi-Monthly..	New York.
STREET RAILWAY JOURNAL.....	Monthly.....	"
STREET RAILWAY GAZETTE.....	"	Chicago.
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THE STEAMSHIP.....	"	Leith, Scotland.
BULLETIN DE LA SOCIETE INTERNATIONALE DES ELECTRICIENS.....	"	Paris.
JOURNAL OF THE INSTITUTION OF ELECTRICAL ENGINEERS.....	"	London.
JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES.....	"	Chicago.
INDIA RUBBER WORLD.....	"	New York.
TRANSACTIONS OF THE CANADIAN SOCIETY OF CIVIL ENGINEERS.....	Quarterly.....	Montreal.
TECHNOLOGY	"	Boston.
JOURNAL OF THE FRANKLIN INSTITUTE.	Monthly	Philadelphia, Pa.
MECHANICS.....	"	"
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JOURNAL OF THE ELECTRICAL SOCIETY.	"	Tokio, Japan.
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LOCOMOTIVE ENGINEER.....	"	"
COLLIERY ENGINEER.....	"	Scranton, Pa.
ELECTRICAL, MECHANICAL AND MILLING NEWS	"	{ Toronto and Montreal.
GIORNALE DELLE COMUNICAZIONI.....	"	Rome.