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Proceedings at One Hundred and Forty-second Ordinary General Meeting.

17th April, 1924.

The One Hundred and Forty-Second Ordinary General Meeting of the South African Institute of Electrical Engineers was held in the Assembly Hall, Scientific and Technical Club, 100, Fox Street, Johannesburg, on Thursday, the 17th April, 1924, at 8 p.m., Mr. B. Sankey (President) in the chair. There were present 28 members, 3 visitors and the Secretary.

MINUTES.

The Minutes of the March meeting, as printed in the Journal for that month, were taken as read, and confirmed.

Election of New Members.

Messrs. G. J. Moore and C. J. Monk were elected scrutineers of the ballot for the election of new members, and, after their scrutiny, the following candidates were declared duly elected:—

Associate Members.

Lloyd, Richard, Electrical Engineer (Resident), Municipality, Middelburg, C.P. Proposed by Mr. R. F. Botting, seconded by Mr. W. W. Jones, supported by Professor J. H. Dobson.

Lewis, Stakesby Vyvyan Reginald, Electrical Engineer, P.O. Box 2, Frankfort, O.F.S. (transfer from Technical Associate). Proposed by Mr. C. N. O. Dutton, seconded by Professor J. H. Dobson.

GENERAL BUSINESS.

VISIT TO VEREENIGING ON 22ND MAY, 1924.

The President: Under the heading of General Business, I wish to call your attention to an announcement in the *Journal* of an official visit to Vereeniging. Circulars will be sent to all members, with a tear-off slip to be returned, and I would ask members who wish to go to send in their notification as early as possible so as to enable us to make the necessary arrangements.

SMOKING CONCERT.

The President: The smoking concert and hot-pot supper took place on 29th March and was quite a successful function. There were not as many members present as we had hoped for, but I trust a similar evening will be repeated in the near future.

Mr. G. J. Moore (*Member*): I wish to express our congratulations to the President in making such a success of the social evening.

The President: The congratulations of the members should be accorded to the committee who organised the concert. I should like to express our thanks to the artists—all of whom are employed in the Power Station workshops—who volunteered their services. The talent was above reproach, and our thanks are due to the committee and the artists for a very successful evening.

Leave of Absence.

The President: This is the last meeting at which I shall have the privilege of presiding, as I am leaving for England shortly. I have to ask you to kindly grant me leave of absence for about three or four months. In the meantime Mr. H. W. Clayden or Mr. V. Pickles will deputise for me.

Prof. W. Buchanan (*Past-President*): Mr. President, when you get to England it will be fitting if you could attend some meeting of the parent Institution in London. If so, would you be good enough to convey our greetings and let members of the Institution know what we are doing in South Africa. I think it would be appreciated by all of us, and I wish to put to the meeting a formal resolution that you be asked to convey our greetings to the Institution.

Mr. G. J. Moore (*Member*) seconded.

Mr. V. Pickles (*Vice-President*): I would like to support the motion before the meeting.

The President: Before putting that to the meeting, I should like to say that I hope to have an opportunity of attending at least one meeting of the Institution in London. I have a letter from Dr. Alexander Russell, the President, who was my principal at Farraday House many years ago, and he has given me an invitation from himself and Mr. Rowel, the Secretary, to visit the Institution at any time and get an insight into the working of the parent body.

The resolution was put to the meeting and carried unanimously with applause.

"ELECTRICAL SYSTEM OF WELDING."

By C. N. O. Dutton (*Member*).

The autogenous welding of metals by the electrical method has been known for many years, especially by the method of operation called the Bernados system, but it is only a few years ago that serious attention was directed to electrical welding, and during the Great War its application in engineering products advanced considerably, and I propose to conclude this paper by exhibiting on the screen a few engineering structures built in South Africa by electric welding.

Electrical welding may be divided into the following sections, namely:—

1. The Bernados system.
2. The Metallic Arc system.
3. Spot and Butt welding.
4. Metallic tipping or depositing by the Electric Arc.

The extent of this paper will not permit of a detailed history of these systems, or of the numerous experiments which have done so much to achieve the position the art has reached to-day, but a short description of these will be sufficient to illustrate their advantages for the metals to be welded or treated by each system.

1.—The Bernados System.

This system is named after its inventor, who is credited with having first used the electric arc to weld metals together under its intense heat. The carbon pencil or rod is the negative pole, and the work or object to be welded the positive pole.

The rods may be advantageously made of graphite composition, and vary, according to the work required, from ¼in. to 1½in. in diameter; direct current is essential, the process requiring from 100/800 amperes with 75/80 volts pressure.

The writer has little personal experience of the Bernados system, so cannot give any first-hand data or views on its suitability for various classes of work, but it would appear to be largely used for direct fusion of metals of large area and thickness, and the repair and filling up of heavy castings.

2.—The Metallic Arc System.

This system would appear to be forging ahead in popularity, and is different from the Bernados system inasmuch as prepared metallic electrodes of varying thicknesses are used in place of the carbon or graphite rods. The current for its operation may be direct or alternating, varying from 10/250 amperes with 30/80 volts pressure. Electrodes usually range from No. 10 to No. 4 S.W.G., and occasionally larger, and may be of either the bare or flux-covered types.

For the welding of cast and mild steel, and wrought iron, this process appears most suitable and is very economical where electric current is obtainable at low industrial rates.

In the hands of those who are not highly skilled, the appearance of the weld does not compare favourably with that done by the oxy-acetylene process, especially on thin sheet material; in fact, it would appear that anything below ⅛in. plate should not be welded with electrodes except by really skilled operators.

There would appear to be some difference of opinion with regard to the use of flux-covered electrodes, and those that are "dipped" only, and although the former appear to be universally used in Great Britain, such is not the case in the United States of America, where the bare or dipped electrodes is in favour. The writer has investigated this position with a view to arriving at some definite opinion on the subject, and although both have advantages, he is inclined to favour those having a flux covering secured to the rods by means of an asbestos wrapping. These electrodes appear to bring the slag or metallic oxides to the surface better and puddle the molten metal very well. The bare electrode certainly appears quite suitable for single layer work, and works well with cast iron when the article is pre-heated.

To do good welding, it is necessary to select electrodes of the right size and quality for the work, and for mild steel plate work the following information may be relied upon:—

Thickness of work.	Size of Electrode. S.W.G.	Current Recommended. Amperes.
14 S.W.G.	14	40/60
12 ,,	12	40/60
10 ,,	12	40/60
3/16in. Plate	10	60/90
¼in. Plate	8	80/120
⅜in. Plate	8	80/120
½in. to ¾in. Plate	6	100/140
¾in. to 1½in. Plate	4	130/175

The electric welding of mild steel plates has been accepted by all authorities as standard practice. After exhaustive tests, Lloyd's register and all Government Departments have now declared this process as acceptable to them in their specifications, and it is conceded that autogeneous welding by the electric arc does not affect the strength of the materials if carefully executed by skilled operators.

TESTS.

The tests made on three welds done by metallic electrodes, of a well-known make, are as follows:—

Description.		Size in ins.
Special Tensile A	...	·937 x ·410
Special Tensile B	...	·993 x ·382
14 per cent. Manganese	...	1·08 x ·22

Area in ins.	Distance between gauge points in ins.	Maximum Stress. On section. Tons.	Maximum Stress. Per Sq. in. Tons.	Elong. per cent.
·384	1	12·2	29·2	10·0
·380	1	13·5	35·5	6·0
·237	—	11·0	46·3	7·0

The above are all flux-covered electrodes, and the two former can be safely used on boiler and other high pressure work.

The latter are eminently adapted for building up points and crossings, crusher jaws and the like, which have been worn down, and which, were it not for electric welding, would have to be scrapped.

Every class of work is a problem in itself, and notes should be taken for future reference, and I venture to say that if an operator takes a real interest in his trade and studies carefully the different work he does, the results can be absolutely relied upon to conform to the most exacting conditions of tests.

The electric welding of cast iron has only been successful where the highest skill can be employed, and the article must be pre-heated to a dull red before welding commences, and the greatest care must be observed in cooling the casting, or cracks will result. A method of repairing iron castings that cannot be pre-heated by the "studding" method has been adopted with some success. Briefly explained, this method consists of veeing out the line of the fracture, and then inserting screwed steel studs along the line of the crack. The molten metal is then fused along the vee, and melting the projecting studs into the mass.

The writer, however, is not yet convinced that perfect autogeneous welding of cast iron by the electric arc method is possible, by the method of preparation mentioned above or by the electrodes at present obtainable. Monel metal electrodes are claimed to solve the problem, but as the writer has not had an opportunity of testing these, he can give no views in this paper.

Turning now to the third type of welding, namely, spot welding, this consists of heating sheet metal between two points to a welding heat, and then pressing the points nearly together, and the metal completely together. This system is very largely used in tinplate and motor car works, etc., and has, for other purposes, been used for joining mild steel plates up to 1in. thick each. The work done is equal to riveting and less costly.

The machines used for spot-welding consist of a primary and secondary of a special transformer, and are rated according to the thickness of plates they are to operate upon. The secondary voltage is in most cases about 2 to 3, the amperes varying from, say, 500 to 100,000 according to the thickness of the material dealt with.

Spot welding can be usefully employed where mass production of moderately thick plates is to be handled, and of such sizes as can be easily handled. Members will perhaps have noted that the handle of their petrol or paraffin tin is spot welded.

In this class may be mentioned the butt-welding type of machine, of which several have recently been installed on the Witwatersrand mines, for joining up drill steel, and, as successful butt welding has been in vogue for many years, it would be interesting to know how it is that this system has only recently been such a success here.

Butt welding is exactly similar to spot welding, except that the secondary of the transformer is short-circuited by the two points to be joined; the point of contact being of higher resistance, it naturally rapidly becomes incandescent and then molten. At this period the points are withdrawn slightly, allowing the arc effect to cause greater heat; the two points are then heavily pressed together and the current cut off, leaving a perfectly fused and mechanically strong joint.

I hope some member who has had practical experience with these machines will be good enough to let us have some more information on their behaviour, etc., on the Witwatersrand.

The butt welding of wheel tyres, wires, rods, and tee welding can be successfully carried out with special machines and are largely used in industries where plenty of specialised work can be provided for them.

The manufacture of chains by means of butt welding has been successfully carried out for some years, and a description and illustration of these types of machines, which carry out this wonderful work, may not be out of place in this paper.

The first slide shows the chain link forming machine, which receives the rod material and forms the links, at the same time coupling to the next link. The second slide

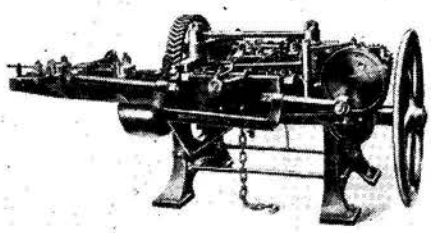


Fig. 1.

shows the welding machine which butt welds the links. All that now remains to be done is to grind off the weld bulge and the chain is complete.

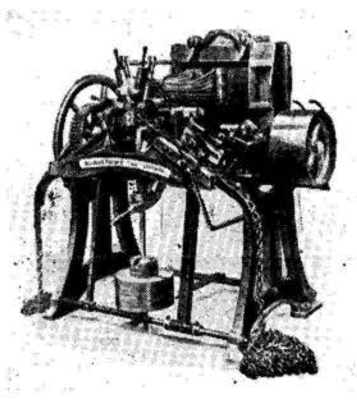


Fig. 2.

The machines illustrated will manufacture chain material up to ⅝in. diameter stock in the short or long link types. The speed of working varies from 10 to 50 links per minute, the welding current required being:

3/16in. to 13/32in. diameters up to 3 k.w.
3/16in. to ½in. diameters up to 5 k.w.
½in. to ⅝in. diameters up to 8 k.w.

The machines illustrated are of French manufacture, and I have here some samples of chain made by these machines.

In considering that these machines are all automatic, and require practically no skilled attention, it can be understood why welded chain can be sold by manufacturers at a trifle over the cost of the raw material.

Under the heading of butt welding we can mention several other special applications, such as the cyc-arc system of securing pins, tubes and studs accurately and neatly to flat surfaces.

4.—METALLIC TIPPING AND BUILDING UP OF TOOLS.

High speed tool steel is a most expensive material and therefore the less one consumes in any large works the better. It is now usual to make the tool or drill shank of mild or cast steel, and deposit thereon electrically a suitable thickness of **tungsten** The tool is then ground to shape and used in the ordinary way.

Electrodes for depositing special alloys can usually be obtained in the following grades:—

Carbon Electrodes " A " to deposit 1·5% Carbon Steel.
Carbon Electrodes " B " to deposit 1% Carbon Steel.
Carbon Electrodes " C " to deposit 0·75% Carbon Steel.
Carbon Electrodes " D " to deposit 0·5% Carbon Steel.
Self-Hardening.—Giving a hard steel deposit.
Manganese.—Depositing 14% manganese.
Nickel Carbon.—Contains 4% N1 and 0·4% C for welding nickel steel. Deposits approx. 3·5% nickel steel.

The self-hardening and manganese electrodes have been largely used on mill parts, such as cams and tappets, and have also been used with success in building up worn crusher jaws, elevator buckets, train crossings, etc. Work done by these electrodes must naturally be ground afterwards to shape.

Fig. 3

When one becomes really interested in electric welding and depositing, it is remarkable how much one can recover from the scrap heap. Almost any steel article can be made serviceable again, and it has been known that cams and tappets built up, as shown on the screen, have lasted longer than new ones.

Fig. 4.

Electrodes have now been produced to deposit stainless steel and monel metal, and the latter should prove useful for building up worn pump spindles and other steel parts subjected to the corrosive action of mine water.

The system of electric arc welding by means of metallic electrodes, is most para-

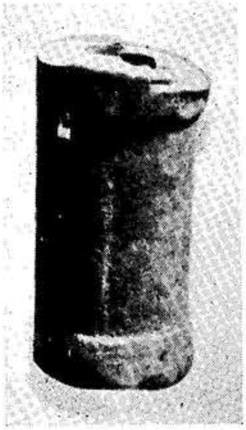


Fig. 5.

mount in South Africa, and it would therefore be of interest to describe the various

Fig. 6.

systems adopted to provide the necessary operating current.

ALTERNATING CURRENT.

Bare electrodes are used with difficulty when operating with A.C. current, and it has been found that even with flux-covered electrodes the welding inclines to pit, or leave minute pin holes in the weld.

It is necessary to have a steady supply voltage, and periodicity given, and a skilled operator. Then the work is certainly good, and compares very favourably with the work done by the direct current arc.

Welding is a single phase load with a lagging power factor, and is therefore likely to affect the primary supply current to the transformer to the extent of the transforming ratio. However, where more than one welder can be employed it would be advisable to consider taking single phase current from a three-phase transformer by the method of connecting the secondaries in series, with one winding reversed. This equalises the currents in the primary phases, but in two of them the currents are 60° out of phase, one leading and the other lagging.

Alternating current welding requires 75 to 90 volts on open circuit. The difference between this and the arc voltage is taken up by means of a reactance in the circuit. The capacity for a single welder outfit to do up to No. 4 S.W.G. electrodes should be about a 12 K.V.A. transformer.

There are several types of welding transformers and transformer regulators designed, important amongst which are Davies-Soames Automatic Regulator (Daysohms Ltd.), whose connections and characteristic curve are shown on the screen.

This apparatus resembles a wound rotor induction motor. The stator and rotor windings are in series, and are of equal numbers of turns. The rotor is free to rotate within limits against certain restraints. In the no-load position the windings produce nearly co-axial opposed poles and magnetomotive forces in the iron, with a minimum reactance. When current in passing the rotor tends to rotate in the direction increasing the resultant flux and reactance, up to the position where the poles are co-axial and the magnetomotive forces are added. This is the position of maximum reactance. With 2-pole windings the angular movement from minimum to maximum choke is obviously 180°. The rotation is opposed by a spring, the force of which can be regulated and damped by a dash-pot. The minimum choke can be regulated by an adjustable stop which limits the rotor movement in the direction given by the spring.

To adjust the regulator for welding, the spring is regulated for the desired welding current, and the stop is fixed for the choke corresponding to the arc-striking current. The open-circuit voltage is that of the transformer, but on striking the arc the circuit voltage drops instantly, due to the operation of the choke, and the rotor moves until the current torque is balanced by that of the spring. In practice it is found that this regulator gives a very nearly constant current, viz., that at which the rotor and the spring torque just balance, with a very sharp voltage-drop if that current is exceeded. This drop is not dependent upon the movement of the rotor. As the voltage can only increase sensibly with a decrease in the current, a long arc cannot be maintained, being extinguished by the current-drop.

The latest form of this alternating current arc welder embodies the same principle but in which the striking and the welding current are separately adjustable, and consists of a transformer and choke coil in one unit, the choke coil being, as before,

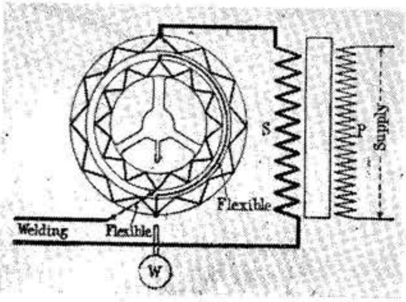


Fig. 7.

provided with a dash-pot and adjustable stops to limit the movement of its keeper, and a spring to return it towards zero, which will give the full range of 25 to 200 amperes in infinite gradation. This unit

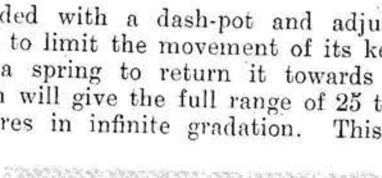


Fig. 8.

is arranged for direct connection to any alternating-current means, and as it weighs only about 3 cwts., and is fitted with castors, it is very easily moved about a works.

Direct current welding would appear to be most popular, and it seems to give better welding results, even in the hands of a semi-skilled operator.

For general purposes, the maximum loading is 200 amperes at 70 volts, on open circuit. The regulation of the D.C. sets is accomplished in several ways, and the ideal characteristic is a flat voltage curve from zero to the full current for which it is adjusted, and a very rapid voltage drop with any greater current. It is most desirable that current fluctuations caused by unavoidable variations in arc-length shall be checked and limited.

The general requirements are therefore as follows:—

1. A drooping characteristic for any current beyond that fixed by adjustment.
2. A uniform voltage for currents up to the set or adjusted load, with little or no increase at no load.
3. Very rapid regulation to counter the effect of arc variations.

The arrangements devised to meet the above conditions may be classified as follows:—

1. Excitation methods; combinations of self-excitation, separate excitation, direct and reversed series excitation. Special arrangements of magnetic circuit, pole disposition and external regulators acting on the exciting circuits.
2. Regulation of speed or troque by electrical control or transmission clutch from driving medium.
3. External regulators controlling the welding circuit through resistances acting on the exciting medium.

A few of these systems are described as follows:—

MACFARLANE SYSTEM (A.W.P.).

The diagram of this system and a characteristic curve with the regulator in three different positions is shown, also a curve of test of a belt-driven single operator set of the same type. The machine was welding on 200 amperes at 30 volts for half an hour, and 150 amperes at 30 volts for one hour. The curve shows the characteristic with six different positions of the shunt regulator.

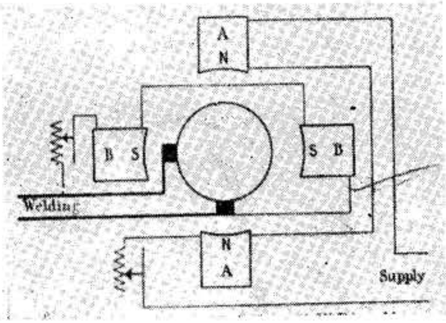


Fig. 9.

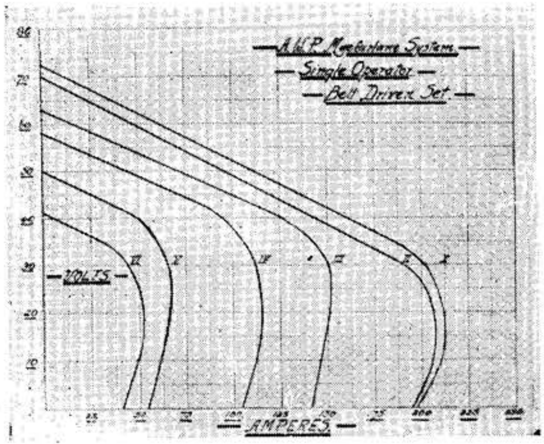


Fig. 10.

The connections of the MacFarlane system are:—

A = Shunt winding on one pair of diametrically opposite poles separately excited.

B = Shunt winding on other pair of diametrically opposite poles, separately excited.

A and B are wound in the same sense, and each has a Rheostat in series for the regulation of the welding current. The pole piece form, etc., are designed to facilitate armature reaction, giving a result similar to that of a reversed series winding.

METROPOLITAN-VICKERS AND WESTINGHOUSE SYSTEMS.

It is claimed by the designers of this system that in order to obtain better efficiency, the series resistance must be entirely dispensed with, and the stabilising function of the resistance must be embodied in the generator.

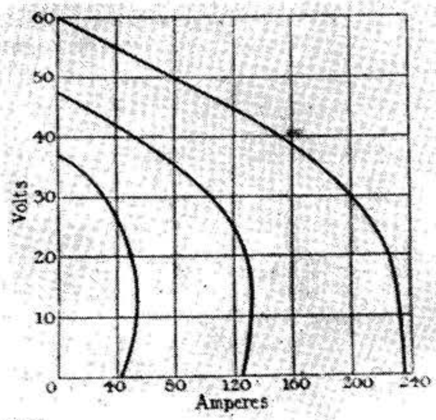


Fig. 11.

It has a variable voltage characteristic, and the limiting feature in maintaining a stable arc is that this line must not be too nearly horizontal, and on the other hand it must not be too steep.

The machines are compound wound generators, with a separately excited shunt field winding, and a reversed series winding, carefully balanced to give the correct voltage characteristic.

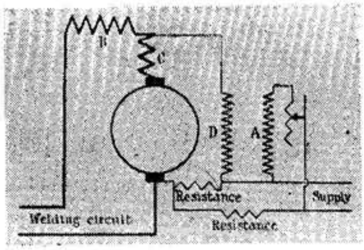


Fig. 11a.

The generator is adjusted for different welding currents by means of the shunt field regulator, which changes the open-circuit voltage, each change producing a parallel characteristic. A further adjustment is provided on the series field winding whereby the slope of the characteristic may be changed.

Single machines for more than one operator are supplied with stabilising resistance units, each operator having one of these resistance units in circuit. For metallic arc welding the resistances are arranged to regulate the arc current from 10 to 170 amperes, in current increments of 10 amperes.

GENERAL ELECTRIC (AMERICAN) SYSTEM.

This machine is of the split pole type and the connections are illustrated, these being:

A = Shunt winding, self excited, on main poles, viz., on the horizontal diameter.

B = Shunt winding, self excited, on cross poles, viz., on the vertical diameter.

C = Series winding, in welding circuit, on cross poles, reversed with respect to the shunt winding.

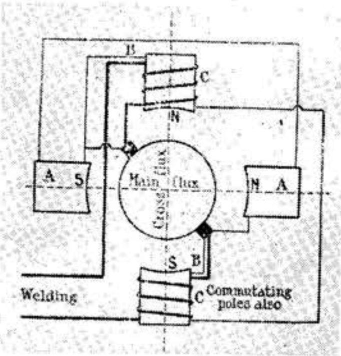


Fig. 12.

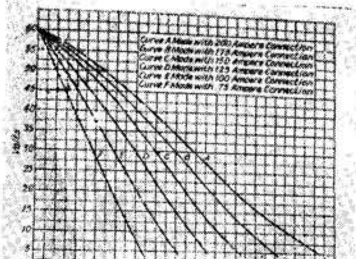


Fig. 13.

The main poles are normally saturated, the cross poles are not saturated but provide a path for the armature reaction flux, which is assisted by the series winding. The series turns are adjustable for different welding currents.

At a given load the cross field is reversed by the sum of the armature reaction, and the series winding effects; on short circuit the reverse field cancels the main field, giving zero voltage. At any load the voltage is proportional to the arithmetical sum of the main and cross fields. I believe the G.E. Co. have further improved their design of these machines.

WILSON PLASTIC ARC SYSTEM.

This equipment has a carbon pile resistance, with a solenoid in the welding circuit, acting against a spring which compresses the pile. The adjustment is made by shunts on the solenoid.

The writer has experience of one of the above, driven by an automobile type of engine; the performance of the welding equipment gives great satisfaction, the regulation being particularly reliable. It is, however, difficult to understand why such complicated regulating devices are used when practically equal results can be obtained from the machines previously described, which achieve their object without such elaborate gear.

The time and space does not permit of giving descriptions of other systems of direct and alternating current welding systems, all of which have no doubt their claim to solving the ideal conditions required from designers for supplying a constant current and voltage for welding purposes.

POLARITY.

The practice is to make the work positive and the electrode negative. With metallic electrodes the reason for making the work positive is that, as more heat is evolved at the positive, the greater conductivity of the work is countered, and the work surface raised to the fusing point with a smaller current than would otherwise be necessary. The total heating of the work, the expansion and other troubles, due to such heating, are reduced.

Samples of Work.

I have here to-night several samples of work done by electric welding, and I invite members to carefully inspect these at the conclusion of the meeting. Samples are also exhibited of a wide range of flux-covered and light-coated electrodes, and also the American type of bare electrodes. These electrodes cover the field of general work done here, but some special electrodes recently introduced have, I regret to say, not come to hand in time for exhibition.

As regards the samples of work done, I will briefly describe them in order:—

No. 1: Piece of 2in. steel shaft prepared ready for welding.

No. 2: Piece of 2in. shaft, electrically welded.

No. 3: Piece of 2in. shaft half turned over weld.

Shafts up to 9in. diameter have been successfully welded. The mine cam shaft illustrated on the screen has been repaired in the manner shown. The difficulty with regard to the repair of camshafts is due to the fact that they usually break, owing to the fatigue of the material, mainly caused by the vibration they are subjected to in the mills. Naturally they must be carefully annealed before and after welding, otherwise they would only break down again, say, 6 to 12 inches from the weld. Neglect of careful attention to the annealing has caused many failures, and for which the electric welding has been blamed.

No. 4.—This is a piece of cast iron which has been joined together by electric welding, without pre-heating. Although close examination does not exhibit a line of joint, it is there nevertheless, and could be detected under a powerful magnifier, and it is along this line of joint that the weakness exists. The weld can be machined.

No. 5.—This is a piece of cast iron preheated and welded by the oxy-acetylene method, the welding medium being a fine quality of pure ferro silicon. This weld has become perfectly homogeneous with the main material, and can be machined.

No. 6.—This is a short piece of ¾in. mild steel plate, veed and welded electrically; on the reverse side it has been machined.

No. 7.—Shows similar operations on ¼in. mild steel plate.

Nos. 8 and 9.—These are short pieces of ¼in. and ⅛in. mild steel plate welded electrically, machined, and bent double when cold in a vice. These illustrate the strength and reliability of welded steel plate.

No. 10.—Illustrates a piece of mild steel angle, welded together. The strength of the material is not impaired, and this method has been found most useful in joining up short pieces of angle steel, instead of consigning them to the scrap heap.

No. 11.—Shows a crown section of a roof truss composed of mild steel angles and steel plate. This work is stronger than riveting and if the work can be laid out on the site of the building, then marking out, drilling, etc., can be dispensed with. Several large roofs in Great Britain and America have been entirely constructed by this method.

No. 14.—This represents a lathe tool roughly tipped with tungsten, the shank being mild steel.

No. 15.—Here is a similar built-up lathe tool, ground to shape and ready for the turner to use.

The repair of rock drill parts by electric welding and their associate machines, has saved the industry many thousands of pounds per annum; without electric welding they would have to be consigned to the scrap heap.

I have now pleasure in reproducing on the screen actual photographs of work done in Johannesburg by means of electric welding.

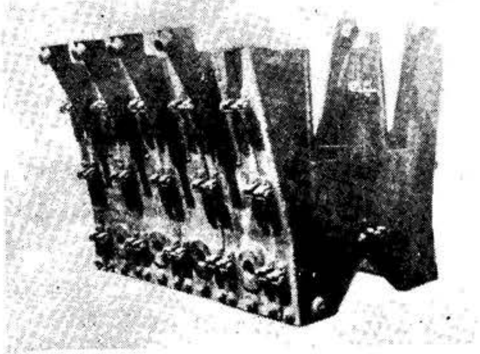


Fig. 14.

Water jackets for the Transvaal Silver and Base Metals Smelting Furnace, Argent, Transvaal.

The jackets are constructed of ⅜in. mild steel plates, and are entirely welded by the electrical process.

Members will please note that the design of these jackets does not permit of their being manufactured in any other manner except by welding.

The jackets have stood up to their duty exceptionally well, and, I believe, have exceeded their estimated life.

Vacuum tanks for the Crowe system of slimes treatment.

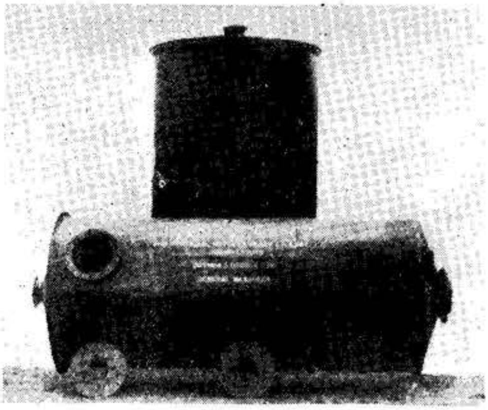


Fig. 15.

These tanks vary from 4ft. to 6ft. in diameter and are all 12ft. high. They are constructed of 3/16in. bodies with ¼in. cones. They are electrically welded throughout and have been tested before dispatch to 25 lbs. per square inch pressure. Eighteen of these tanks have been built to date.

Figs. 16 and 17 show a motor car gear wheel before and after building up electrically. The wheel has still to be re-cut and hardened.

I may say that this gear wheel was repaired two years ago, and is still in service.

The last illustration is of electrically welded 20 cubic feet standard mine stope truck bodies. The one illustrated was made nearly two years ago, and is still in service down one of the far east mines. At an

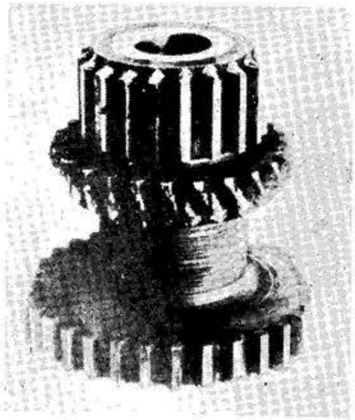


Fig. 16.

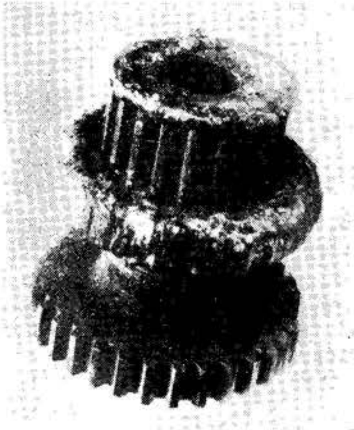


Fig. 17.

inspection made about four months ago, the body had not suffered in any way from the rough usage it had received, and was perfect in shape. It is still under test in another portion of the mine.

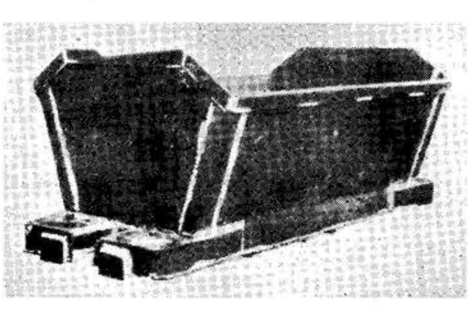


Fig. 18.

Although electrically welded mine truck bodies may be a little higher in first cost, it must be borne in mind that their maintenance is "nil," as there is more stability than those of riveted construction, and there are no rivets to come loose.

When the side plates wear they can be cut out by the oxy-acetylene torch, and a new plate welded in by the electrical method. As there is no overlapping of plates required for welding, there is less to cut out and replace.

In concluding this paper, I must thank you, Mr. President, the members of the Institution, and the visitors, for the very kind attention you have accorded me in my endeavour to describe and illustrate one of the side lines of electrical science.

The author also desires to acknowledge with thanks the assistance rendered him by Major Caldwell in the preparation of certain portions of this paper.

J. Burnard Bullock (*Associate Member*): The wonderful progress made in electric welding during the war period is deserving of more than passing mention. The process enabled the engineering industry to achieve, with inadequate and diluted labour, results which would have been quite impossible with previous methods, even without labour restrictions.

I came across a most striking object lesson in the course of some work on submarine mines. While experimenting on patterns made and used during the war, we used a number of old Service pattern mines as floats. These latter offered an extraordinary contrast to the war-time mines, in that they were fine examples of boiler-making, made up of a number of sections and simply bristling with rivets. No wonder that our stock of this type of mine, when war broke out, was a few paltry thousands, enough perhaps to lay one small minefield, as minefields came to be reckoned during the war.

The war-time mine consisted of two pressed hemispherical steel sections united by means of a circumferential weld. This type I subjected to heavy under-water explosions and I had no case of failure of the welds, unless the mine case were split elsewhere, and virtually crumpled up entirely. Had it not been for the pressed and welded type of mine referred to, the huge minefield laid in the North Sea would have been out of the question.

I quite agree with the author that it is remarkable that electric welding has only recently come to be applied to hollow drill steel. The process only now being adopted has been used elsewhere for ten or twelve years.

It is arguable that in this case the makers of apparatus have not been in touch with the needs and possibilities of these fields. Even when an apparatus has now made a belated appearance here, the method of ensuring that the centre hole be tapped clear and of normal diameter at the weld would appear to have been left for local experimenting.

The first idea was to use small wooden plugs, whose remains had to be got out after welding. When this proved too troublesome, the method of expanding the ends of the portions of hollow steel before welding and dressing down to normal diameter after welding was tried. This entailed an undue expenditure, and finally the simple expedient of directing a jet of compressed air through the hole at the moment of welding was tried, with extraordinary success.

As a result, the electric reconstruction of hollow drill steel seems likely to become an important factor in reducing underground costs on the Witwatersrand.

The President: I think you will agree, gentlemen, that we move a hearty vote of thanks to Mr. Dutton for his paper, and we hope there will be an extended discussion at future meetings. (Applause.)

DISCUSSION ON RECENT DEVELOPMENTS IN AUTOMATIC TELEPHONY.

(By T. H. Watson, *Member.*)

G. H. B. Bernard (*Member*): Owing in one case to illness and in the remaining cases to absence from Johannesburg, I have been unable to attend a meeting of the Institute since Mr. Watson read his paper, and I welcome this opportunity of reading even the few notes I have found time to prepare in connection with Mr. Watson's paper, which is one of great interest to all connected with the fascinating problems of automatic telephony, and particularly so to myself, because I happened to be in England, and in close touch with keenly interested engineers of the B.P.O. and manufacturing firms for some months after Mr. Watson's return to Johannesburg.

I congratulate him on his paper, especially on the illuminating photos and diagrams which he has collected, but I must ask him to forgive me if I use English terms (which are more familiar to all of us, himself, I am sure, included) rather than the American terms which appear in his paper.

As is usual, for convenience, in discussing a paper of this nature, I will try to arrange the comments I have to make in an order corresponding to that of the paper.

Preselectors (Line Switches).—I was somewhat puzzled when I heard the paper read, by the data given in regard to comparative tests of 25-contact and 10-contact banks with and without common interrupters, as the results differed so emphatically from the experience gained in England by manufacturers and the Post Office, as the result of several years of successful running of the 10-way rotary preselector (line switch) driven by common interrupters.

Two instances will serve to show the quality of service given under these conditions, but very many similar cases could be mentioned. The special instances I have in mind are, *first*, that in the Grimsby Automatic Exchange, which now has over 1,800 preselectors in service, not a single preselector fault was recorded by the Post Office in twelve consecutive months, and, *second*, that in the considerably older Exchange at Port Adelaide, Australia, drive faults on preselectors were so few as to represent one fault per switch in every 214 years, taking into consideration faults of every kind on preselectors, it was found that one fault occurred per switch on an average every 77 years!

It was not until I read the December *Journal* that I realised that the 10-contact line switch he had in mind is the now obsolescent Keith switch. Mr. Watson refers to trials in 1909 of common interrupters for the line switches in Strowger Exchanges in the U.S.A. The line switches in this case must have been of the Keith type, as rotary line switches have only been adopted during the last few years by the Automatic Electric and associated companies. I agree that double connections were a trouble with the Keith switch, but with the preselector with common interrupter using the test circuit developed in the Siemens system, double connection is practically impossible, and has certainly caused no trouble during many years' practical working.

In comparing common interrupters with self-drive, Mr. Watson has not mentioned that the difficulty of keeping thousands of self-driven switches in tune is a very real one, and obviously needs more maintenance men than a few very robust and reliable common interrupters.

There may be a much greater risk of dual connections if common interrupters are used in the system he describes, but as already stated, this risk is negligible with the test circuit adopted in the Siemens system, as is shown by the fact that though common interrupters have long been used by the B.P.O. in automatic exchanges on this system, no complaints have yet been made of trouble due to double connections, though their test for this fault is most drastic.

In connection with the size of bank for a line switch, I have already mentioned in discussing an earlier paper the prime disadvantage of the larger bank used without 2nd preselectors, viz., increased cost per line and lower efficiency. It is claimed for the 2nd preselectors that they facilitate the tracing of a call through the exchange, while experiments show that their use increases the efficiency of the second selectors as well as of the first selectors.

It may be mentioned here that although 25-contact line switches are to be used in London, 20-contacts only are actually available for links to the first selectors, partly because the Post Office has stipulated that the first preselectors (line switches) *must* return to the normal position (this is a reversal of the preliminary arrangement mentioned on page 278 by Mr. Watson).

The two main reasons for this stipulation are that if they do not return to a "normal" (or "home") position after each call, the effectiveness of "grading" the links from them to the first selectors is reduced and that an indicating lamp has to be used per switch to show whether it is in use on a call or not. Apart from the extra cost of these lamps, their use considerably increases the watts per call, and if switches are used to cut them out when not required, they not only increase costs, but complicate circuits.

I must pass rapidly over the interesting descriptions of various well known variants of the two co-ordinate selector switch, pausing only to express a little surprise at the revival of the long ago discarded scheme of using hinged doors to allow switches to be mounted on both sides of one rack (photos 4 and 5), and to mention in connection with the unit I.D.F. shown on the same page 254, that the sectional I.D.F. gives, in the opinion of B.P.O. engineers, better and cheaper cross connecting facilities, and that further economy is to be effected in the London exchanges being constructed by one firm, by utilising the standard terminal strips on their first preselector and final selector racks. Though used for cheapness, neither type is quite as satisfactory as a single I.D.F. for the whole exchange.

Operating Voltage.—It would be interesting to know on what Mr. Watson bases the statement that at 60 volts there is a risk of contacts cohering, especially on impulse circuits. Probably only on laboratory experiments, since many years of practical experience of exchanges using this voltage show that the alleged risk is a mere bogey. As a matter of interest, the Grimsby Exchange (the oldest using 60 volts in England) has the smallest number of faults per line of any automatic exchange, certainly in Great Britain, and probably in the world.

The utter lack of any foundation for the curious suggestion that the manufacturers of systems using 60 volts were unwillingly forced to do so because their apparatus could not work satisfactorily on a lower voltage, is shown by the fact that identically the same switching mechanisms as are used on 60 volts are in successful operation in exchanges using 48, and even 24 volts. At 60 volts, speech transmission, especially over long lines, is very much improved, and in Australian exchanges even higher voltages are used for important long lines.

The Director System.—In his preliminary remarks, Mr. Watson accidentally claims that the use of this system makes it unnecessary to make *any* change in the directory numbering of *any* exchange. It is clear, of course, that at least 999 numbers in every exchange of 1,000 or more lines must be changed, since each "number" in an exchange must have as many digits as any other.

Consideration of diagram 9 will show how easily mistakes may arise in dialing. Take, for instance, such a number as ROO-547 (Roodepoort 547). Turning to page 276, we see that this is really 766547, but what is easier than to dial R-00547, which corresponds to 700547, a very different number? The same applies to the letter I, which corresponds to the figure 4, but for which the figure 1 may easily be mistaken.

While on the subject of dials, it is interesting to note that the Director system enforces a pause between trains of impulses (digits) to allow time for "hunting" over 10 contacts (see page 265).

This enforced minimum pause has for years been a feature of Messrs. Siemens Bros.' dial, and in a simplified form is incorporated in their latest design now used as a standard by the B.P.O.

The adoption of this distinctly complicated Director system, which so far exists in model form only and does not cover *all* the facilities required for London, is perhaps one of the boldest experiments undertaken by the B.P.O., and there is no doubt that the process of modifying and adapting it to suit practical conditions will provide many interesting problems for the engineers of the B.P.O. and the firms who are making the equipment, of which there are three (or four, if we count separately the now allied A.T.M. and W.E. Companies).

Undoubtedly the Administration was attracted by the flexible numbering scheme which was made possible by combining the W.E. Company's idea of using two or three letters as part of the subscriber's number, with the idea used in Siemens and other semi-automatic systems of altering the first few digits to suit existing inter-exchange junctions. This flexibility, however, has to be paid for, and in most cases it will be found that the increased complexity outweighs this advantage.

A comparatively small area such as Johannesburg can be perfectly satisfactorily served by a five-digit system (possibly with a few six-digit satellites) and this has been proved by the experience of much larger towns, such as Sydney and Melbourne.

Some idea of the complexity of the Director system is given in the paper, and it will not have escaped notice that more switches are operated in setting up a connection than are used during conversation, but it may surprise many to count up the number of switches used in setting up the typical connection to POR (tree) 3456, outlined on three pages of the paper (263/5).

If I correctly understand this description, the operations needed *after* dialing commences are as shown in Table 1. I will leave those interested to count up the switch movements needed, but the number of switches affected is 21, of which 12 are held for the duration of the conversation. As a contrast, Table 2 shows that if a straight five-digit system is used, only four switches are affected, all of which are held during conversation.

Turning to the time taken to set up the connection, I see that by a curious slip Mr. Watson says the Director takes "exactly" 17 seconds. Apart from the difference between quick and slow dialing, the time must vary according to the number of "junction" impulses necessary, which may vary from none to six. For the London seven-digit system, the time using Directors will be between 17 and 24 seconds, *i.e.*, 7 to 14 seconds longer than it takes to dial seven digits.

A straight five-digit system sets up a connection in 6 or 7 seconds, and involves no delay after dialing.

These considerations make it fairly clear that the possible economy in junctions and the value of a flexible numbering scheme must be very important indeed before so complicated a system as that proposed in Mr. Watson's paper is worthy of consideration.

We have as yet no experience of the practical working of a Director equipment, so that it is only possible to guess at the maintenance cost of the sets of switches to which the name Director is given.

It is, however, natural to expect that since the number of switch movements of a Director set per call, and the number of calls it handles per day, are both many times as great as for an ordinary selecter, faults will be correspondingly more numerous.

Moreover, they are much more serious in their effect on the exchange as a whole, because the percentage overload thrown on the survivors of a Director group, is far higher than that thrown on the survivors of a group of ordinary selectors, since an "ordinary" group consists of far more units.

(*For Tables see next page.*)

"THE ELECTRICAL KITCHEN FOR PRIVATE HOUSES."

By Prof. H. Bohle, M.I.E.E. (*Member*).

(*Journal*, October, 1923.

Contribution by Mr. V. Pickles, M.I.E.E. (*Member*).

Professor Bohle has given us a useful paper which, as Professor Buchanan said, has lifted the subject of electric household appliances out of the rut of commercialism. He strikes the weak spot in these appliances when he says they should be fool-proof, easily repaired and durable. My own experience is that for convenience, an electric iron, or a cooker or a kettle cannot be approached by any of the older-fashioned appliances, even including the much advertised gas heated ones. A kitchen stove is an antediluvian apparatus by comparison, and I doubt very much whether Mr. Val Davies could bring practical proof of his contention that food cooked in an electric oven is disastrous to health. In any case this surely is merely a question of design, for I am under the impression that with electricity one can control temperatures at will anywhere between luke-warm and 3,000°C.

But these electric appliances are not yet fool-proof. An electric iron is such an innocent looking thing that occasionally one forgets to switch it off and is only reminded of the omission when it falls to the ground, having burnt its way through the table top. The same with kettles or hot plates. These are so designed that if the heat is not removed as it is generated

(*Continued on page 379.*)

TABLE 1.

OPERATION.	SWITCHES OPERATED.	
	Director Switches.	*Other Switches.*
Caller Dials "P"	"A" Digit Selector	
Do. "O"	"B" and "C" Digit Selector Master Digit Selector	
Do. "R"	"B" and "C" Digit Selector Master Digit Selector	
Do. 3	Thousands Register Master Digit Selector	
Do. 4	Hundreds Register Master Digit Selector	
Do. 5	Tens Register Master Digit Selector	
Do. 6	Units Register	
Junction Impulse 1	Sender Control Switch Sender Switch Impulse Machine	A Junction Group Selector A Junction Preselector
Do. 4	Sender Control Switch Sender Switch Impulse Machine	A Junction Group Selector A Junction Preselector
Do. 7	Sender Control Switch Sender Switch Impulse Machine	A Junction Group Selector A Junction Preselector
Do. 3	Sender Control Switch Sender Switch Impulse Machine	A Junction Group Selector A Junction Preselector
Director Emits Digit 3 ...	Sender Control Switch Sender Switch Impulse Machine Thousands Register	A Group Selector
Do. 4 ...	Sender Control Switch Sender Switch Impulse Machine Hundreds Register	A Group Selector
Do. 5 ...	Sender Control Switch Sender Switch Impulse Machine Units Register	A Final Selector
Do. 6 ...	Sender Control Switch Sender Switch Impulse Machine Units Register	A Final Selector

TABLE 2.

OPERATION.	SWITCHES OPERATED.
Caller Dials first digit	A first selector.
Do. second digit	A second selector.
Do. third digit	A third selector.
Do. fourth digit	A final selector.
Do. fifth digit	A final selector.

something happens inside which calls for the expert advice of the husband. And the husband is often busy, or at any rate gives that excuse in order to cover up his incompetence. Sometimes he has just sufficient leisure to take the thing to pieces, and then something more important claims his attention perhaps just when he has found the fault. Whatever the cause, one usually finds that in the electric kitchen, a large part of the plant is out of commission and either in the process of being dismantled or awaiting attention.

In my own household are two electric irons. One ought to be sufficient, but the second one was purchased because a stand-by seemed to be necessary. I was informed the other day that they were both out of service at the moment, and I propose to look into the matter at the first opportunity.

It is an unfortunate fact that one's wife is usually more highly educated in classical lore than in scientific facts and they are not fitted to take charge of ordinary electrical plant. The servants, too, no doubt carry out experiments which, although they are not aware of it, have been carried out before, and my experience in general leads me to criticise the design of most appliances from the point of view of durability. They are not sufficiently robust to be fool-proof, and if more care were given to their construction, even if they were more expensive in consequence, I think it would add much to their popularity. Looked at as a labour-saving device, they are ahead of anything else available, and when one considers that the annual cost of a native servant is between £40 and £60, there is a possibility of making appreciable savings which will appeal to the thrifty housewife. Take the case of the home employing two or three servants. It is possible that the introduction of proper labour-saving devices would enable one to be dispensed with, in which case the annual saving would justify considerable expenditure on appliances of one sort or another. One can imagine many economies of this nature being effected in this country of so-called cheap native labour, and I am surprised that the aspect of the matter has not been brought to the front more by the advocates of domestic appliances.

J. Burnard Bullock (*Associate Member*): With regard to Professor Bohle's paper, it seems to me that adequate co-operation does not exist between architect and electrical engineer.

The architect will turn out a pleasing house externally and internally, and yet not have a single convenience outlet in the whole of the Building. As a result, the dweller in this house, if he wishes to use apparatus other than that which can be run from a lampholder, has to go to considerable expense to have the house practically re-wired, which expense, added to his outlay on apparatus, is quite enough effectually to discourage him.

If suitable provision were made at the outset, the all-electric house would be much more in evidence.

The Institution of Electrical Engineers has already achieved a joint meeting with the Society of Architects in order to stimulate co-operation, and I submit that a similar effort on our part would be most useful.

Another person who is a check on progress is the electrical retailer and contractor, whose attitude, particularly in this area, is often that electrical cooking is a hopeless proposition. He seems content to accept the layman's opinions rather than to endeavour to prove his case and to lead and educate his customers by tackling the proposition in an enterprising manner.

It has been suggested that cooking apparatus be made more robust irrespective of the effect of this upon first cost. It would, however, appear that the only type of apparatus being pushed by the retailer to-day is of the cheapest and most flimsy description. It is apparent, therefore, that the public is not yet sufficiently educated to appreciate anything but cheapness, and until we can improve matters in this direction we shall not make any solid progress.

W. Hilarius (*Associate Member*): This is a very interesting paper, and our thanks are due to Professor Bohle for the very able manner in which he compiled it.

I agree with Professor Bohle that it is remarkable that electric utensils are not more in vogue. But that is not surprising when one considers the cost of renewals, and the manner in which these renewals are fitted by repairmen. The repairman is not entirely to blame, as the manufacturer does not always consider the possibilities of repairs. If we take, for instance, the electric kettle or any class of cooker, the elements are clamped to the bottom of the vessel. The bottom, whether of aluminium, copper or steel, through continuous use, tends to buckle or pull the clamping screws down, thus forming loose spaces where element does not touch, with the ultimate result of element fusing at this point through not being able to radiate the heat as fast as it is generated.

The repairman, as a rule, does not straighten the bottom, but simply puts a new element in and tests it for a few minutes. The owner finds that the utensil burns out again, and puts it on the shelf as an expensive luxury.

In many cases we find the experienced user the biggest culprit, and blames the manufacturer. In my experience a number of water urns of five-gallon capacity, and in use twenty hours out of twenty-four, used to be renewed about every two months, sometimes sooner. After fitting new bottoms of heavier gauge and making new elements, these urns were in use for twelve months or longer.

Elements.

To safeguard against abuse, such as leaving urns dry while switching on, and then filling with water, I consider that elements should be operated at a lower temperature, and a larger heating surface used. In many of these utensils, the heating surface is too small, necessitating excessive temperatures on element wire. This also reduces the possibilities of buckling bottoms.

The convenience of electrical cooking is tremendous. In a moderate sized house it is possible to do away with the native servant, a continual source of trouble and worry; and not only this, but the heat of a kitchen fire going all day and possibilities making the task of the housewife a pleasure. In a household of eight, and using electric cooking, light, and iron, in a six-roomed house, the total units used was 70, of which 30 were at 6d. a unit, and the balance at 1½d., making the total bill for the month on an average £1.

Materials Used for Appliances.

No doubt we would all expect greater efficiency from materials with a high percentage of heat conductivity. But, unfortunately, although the portion exposed to the element conducts heat faster, the portion exposed to the surrounding air conducts the heat away as fast. For this reason aluminium is, I find, not so efficient, and, although it requires less cleaning, the possibility of burns is more likely. In experience, common iron or steel utensils, well tinned or enamelled, appear the best and give less trouble with damaged elements. The possible loss of efficiency can be well compensated for by using the ordinary steamers, *i.e.*, a dish at bottom with potatoes in water boiling, and fitting on top of this two or three dishes with perforated bottoms, the remaining vegetables or fish, etc., being cooked by steam from the lower utensil.

Loss of Heat.

The lagging of ovens and the clamping covers of elements in kettles, hot-plates, etc., is a point not often considered sufficiently In kettles or boilers a system of immersed heater should prove far more efficient, not only from the point of loss of heat, but also causing confused or interference current in water, thus making more use of convection currents.

Instead of fitting elements into an oven I find that a small hot-plate used in conjunction with a "Blue Flame" oven suitably lagged with asbestos, and placing this oven over the hot-plate with a baffle-plate above the hot-plate to distribute the heat to the sides, a very fine and successful oven can be had at quite a low cost, as well as a fuller use of the utensil.

For Larger Kitchen.

An electrical boiler should prove of more use. The elements being of the immersed type, and having automatic control of current and water supply. The steam is generated under pressure to obtain higher temperature and, after bringing steam up to pressure, the automatic switch cuts out most of the element, only allowing a small bypass of element to operate. Boiling water or steam for cooking is always at hand.

The meeting terminated at 9.45 p.m.

WIRELESS SECTION.

The monthly meeting of the Section was held on 3rd April, 1924, at 8 p.m., Mr. Joseph White, M.C. (Chairman) in the chair.

MINUTES.

The minutes of the meeting held on the 6th March, 1924, were read and confirmed.

ATMOSPHERIC ELECTRICITY.

By H. E. WOOD, M.Sc., F.R.A.S.

Over the high veld of South Africa we are well accustomed to the abnormal manifestations of atmospheric electricity in the form of intense and frequent thunderstorms. The general nature of atmospheric electricity has up to the present not received the attention it deserves from scientists, and it presents many great problems to which no solution has yet been found. With the development of long distance wireless communication more attention will probably be paid to the subject, as the successful elimination of "atmospherics" will probably not be achieved until more is known about the origin and causes of variation of the electricity of the atmosphere.

Atmospheric Potential.—Under normal conditions there is always a field of electric force in the atmosphere, or, in other words, the electric potential changes with height, increasing as we go higher in the atmosphere. The potential at any point in the atmosphere can easily be automatically and continuously measured as, for instance, by the water-dropping electrometer. Assume that we have an insulated conducting water vessel provided with a long thin pipe from which a stream of fine drops of water is emitted: the drops of water will carry away charges of electricity until the potential of the jet is identical with the potential of the air at that point. If the vessel is connected to an electrometer, the other side of which is earthed, a measure is thus obtained of the potential of the air at a certain level with reference to the earth. A flame or a particle of radium will act equally in determining the potential of the atmosphere at any point.

It is thus found that the normal potential gradient in the atmosphere is of the order of 300 volts per metre near the surface; the gradient decreases with increasing height and becomes very small above 10 kilometres. Thus as we ascend in the atmosphere the potential is increasing, and when we reach what is known as the conducting layer it will be about one million volts.

Much higher potentials are reached in thunder clouds, potentials of the order of one hundred million volts.

The normal potential gradient is positive measured upwards; it is constantly fluctuating with annual and diurnal or semi-diurnal periods; it is greatly influenced by the state of the weather, being affected by wind, rain, cloud, fog, mist, etc.

As the potential gradient is positive upwards from the surface of the earth, the earth's surface must be charged negatively. Thus we have a negatively charged earth within a conducting atmosphere. This state of affairs is electrically unstable, and so the charge on the earth's surface must constantly be passing into the atmosphere. Yet the potential gradient, and therefore the surface charge, remains undiminished. Hence the earth's negative charge must be constantly replenished. Over the whole earth the amount of negative electricity passing into the atmosphere is equivalent to a constant current of 1,000 amperes.

Theories of Earth's Negative Charge.—(i.) The first idea was that the earth derived its negative charge from moving ions in the atmosphere. Negative ions are more mobile than positive ions. Therefore if equal numbers are present in a given space, more negative ions than positive should strike any body. Thus the body should charge up negatively until a balance was struck owing to the repulsion of negative ions. This theory is discarded because it was found that an insulated body exposed to the air does not acquire a negative charge.

(ii.) If ionised air is passed through capillary tubes, the escaping air is positively charged and the walls of the tube retain the negative ions. This suggests that if the radio-active matter in the earth gives off an emanation and so ionises the air in cracks in the soil, as the air escapes the negative ions are all retained. This theory is not well supported because the ionisation of the air is not affected greatly by changes of atmospheric pressure as it should be.

(iii.) At first it was thought from early experiments that falling rain was always negatively charged, but it is now found that it is more often positively than negatively charged. Hence the earth's charge cannot be accounted for in this way.

Dissipation and Ionisation.—An electrically charged body, exposed to the air, however perfectly insulated it may be, gradually loses its charge. The rate of loss of charge is different for positively and for negatively charged bodies, and it is found that negative electricity is dissipated more rapidly than positive. The rate is greatly affected by the state of the weather; conditions which produce or accompany a stagnant atmosphere give low dissipation; conditions which keep the air in motion give high dissipation.

What occurs is not an actual loss of electricity from the body, but an acquisition of charges of opposite sign by attraction of ions. The reason for the greater rate of dissipation of negative electricity is that there is a preponderance of positive ions in the air near the surface. This is actually proved by drawing air through a cylinder containing a charged rod.

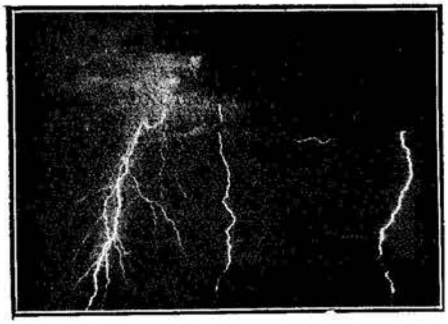
The ionisation of the atmosphere increases with height owing to the action of ionising rays from the sun which do not penetrate very far into the atmosphere.

Lightning and Thunder.—In a thunderstorm the heavy rain which falls at first has a high positive charge; the steady uniform rain which follows is negatively charged.

It was found experimentally by Dr. Simpson that if falling drops of water are broken up by a strong air jet, they acquire a positive charge and the air a negative charge. This has given rise to the now generally accepted theory of the origin of electricity in thunderstorms. Strong ascending currents of air certainly exist in cumulus clouds. The raindrops tending to fall through the upward current are broken up and small negatively charged particles are carried up into the upper parts of the cloud. The positively charged drops form larger drops owing to their being charged and the breaking up process is repeated many times. Gradually the positively charged drops held up by the air current will move out of it laterally and then there will be a burst of highly positively charged rain at the beginning of the storm. The negatively charged rain from the higher parts of the cloud will come down more quietly later.

In this way enormous potential gradients are produced both in the cloud and between the base of the cloud and the earth. The average voltage required to produce a flash of lightning is of the order of 100 million volts, and it is found that these high voltages could easily be produced by the breaking of rain drops.

The duration of a lightning flash is considered to be no more than the one-hundred



Photograph of Lightning: Camera Fixed.

thousandth part of a second. A single flash will generally only neutralise a comparatively small area of a cloud. Its passage through the atmosphere produces by ionisation a conducting path which will be followed by other flashes quickly succeeding

Photograph of Lightning: Camera Moving.

the first. If lightning is photographed by a moving camera a series of identical flashes following the same path at very short intervals will be generally found. It is very doubtful whether the discharge is of an oscillatory nature or whether the subsequent flashes are independent ones making use of a ready-made path.

There are two different types of lightning flash: (a) the "direct" flash, where the potential gradient between cloud and earth or cloud and cloud gradually rises to the sparking voltage of 150,000 volts per foot. With this type of flash the use of lightning conductors to protect buildings, etc., is generally beneficial. (b) The "impulse" flash: here owing to a discharge either between cloud and cloud or from summit to base of a cloud, the potential difference between cloud and earth jumps suddenly to the sparking voltage. Against this type of flash lightning conductors are not of much avail.

The energy dissipated in an average flash of lightning is about 10^{17} ergs. If one flash of lightning occurs every ten seconds the rate at which electrical energy is going to waste is 10^{16} ergs per second, or one million kilowatts.

There is another form of lightning—globe lightning—which has frequently been observed, but for which no explanation can be given.

The Chairman: Gentlemen, I want to thank Mr. Wood on your behalf for his kindness in coming here this evening and giving us his very interesting lecture. It is customary after our lectures to invite any of our members to ask questions on the subject. If anyone has any questions to ask Mr. Wood, I am quite certain he will do his best to answer them.

Mr. Pleass: There is one question I want to ask with regard to meteorites, or shooting stars, as we call them. I remember one evening while listening-in I was very perturbed over certain noises I heard at irregular periods. The noises seemed to point to a defective battery; there was a sort of hiss and a crackle. I tried my high-tension and also the low-tension, but could find nothing. I was beginning to wonder what was taking place. After a little while I gave the thing up, closed down my circuit. I stood out in the air for a minute and was looking skywards; it was a nice, clear starlight night. As I was looking up I saw a meteorite, and then I saw another one. I guessed that when this star or shooting body struck our ether or atmosphere it caused friction through coming into contact with the atmosphere. I put it down to that; I may, of course, be wrong.

Mr. Wood: There may be something in that. I do not know that it would explain your experience altogether; but it fits in, to a certain extent, with what I said. A meteorite is a lump of nickel-iron passing through the atmosphere, and any body passing through the atmosphere like that will produce a very sudden alteration in the difference of the potential; it will disturb the equipotential surfaces; it is travelling very rapidly, probably 40 miles a second, and you might get a temporary effect as a result of that. It is a new suggestion to me; but it is quite feasible that with the sudden variation of the potential due to the rapid passage of the meteorite you might get an effect; but unless you get a steady shower of meteorites, you would not get it for long.

Mr. Pleass: What I had to say was, to me frictional electricity is always interesting, and I thought that this sudden rush of this body through our atmosphere caused frictional electricity which gave off a hissing sound, followed by a smacking noise. It is practically a cold mass passing through our atmosphere and getting hot.

A Member: You have at the top of your sketch of a cloud a negative charge and at the bottom a positive charge. Why do not you get a discharge between the top and bottom of the cloud rather than a discharge taking place from the bottom of the cloud?

Mr. Wood: It does it both ways. You frequently see the whole of a cloud illuminated if you watch these big cumulus clouds before they discharge to earth. Then, also, the top of a cloud is being rapidly spread. There is generally a less difference between the top of a cloud and the base than between the base of a cloud and the earth, so increasing the tendency for the cloud to discharge to the earth rather than through the cloud; but it does frequently happen that you get the whole of the cloud illuminated by internal discharges.

The Chairman: I would like to ask Mr. Wood whether, in his investigations of the northern lights he considered the question of the ionised layer, known as the Heaviside layer, which is assumed to exist at various heights above the atmosphere, a layer which is blamed, rightly or wrongly, for causing roofs on the houses in Johannesburg act as a protection against houses being struck, it may interest members to learn that when some years ago the telephone wires which were run over the roofs of the houses in the town of Berlin were removed, and an underground cable system installed, an appreciable increase in the number of houses struck by lightning was noted.

The Chairman: I would like to suggest to the lecturer that he might complete his subject in a certain sense. I remember listening to Mr. Wood lecturing two or three years ago, when he gave us some very interesting theories, and definite statements, regarding hail. He has not mentioned the word "hail" in his lecture this evening, and I would like to suggest that he complete his subject by dealing with it, if he will.

Mr. Wood: Yes, I did not mention hail, but it is a natural development of this same theory that these drops of water are actually carried up and try to get down again. If you pick up a hailstone and cut it through the centre, you will see that it has got a nucleus, and then a system of skins round it—several of them; just as rings across the section of a tree tell you the age of a tree, so these rings round the hailstones will tell you how many journeys or vain attempts that particular hailstone has taken before it managed to get down to the ground. It begins as a drop of water here (indicating); it cannot fall down—the current may be too great for it, so it goes higher up into the cloud; the higher it goes the lower the temperature, and it gets frozen at a certain height; it tries to come down again, as it comes down again through the very moist contents of the cloud, a film of water condenses on it. It may again be swept upwards and this film will freeze into ice. In this way a hailstone may make several up and down journeys before it reaches the ground, and each double journey adds an extra coating of ice on to it.

Mr. Lowe: I would very much like to ask Mr. Wood if lightning ever strikes upwards. It is a funny sort of question to ask; but the other day I was on a roof in Germiston and observed the lightning conductor on the roof to be very badly charred at the points. I was wondering whether those charred points were caused through current actually leaving the points, or whether it would be due to the lightning striking the points. Could he give us the cause of these charred points?

Mr. Wood: That is just a little extension of what I said here, that the lightning conductor is a dissipator of electricity. When you have a thunderstorm over a building provided with a lightning conductor, that lightning conductor is dissipating electricity all the time. Sometimes it is doing it so fiercely that a blue flame may be detected on the point, which is discharging upwards. The wearing of lightning conductors and the pitting of the points may be produced by this normal action in dissipating electricity. Years ago, before we had so many wires round about the Observatory, we could hear the lightning conductors hissing. I frequently stood on the stoep when there have been thunder clouds overhead and have heard hissing and popping sounds from the lightning conductors; this was due to these discharges taking place. I have often looked at the lightning conductors to see if there was any glow about them. It is frequently referred to in the case of ships. The general illumination all round may be such that you could not see the blue flame on the top of the lightning conductor; but it is seen frequently at sea where you have darkness round you; it is going on all the time a charged cloud is passing over you. It is the lightning conductor performing its natural function of discharging electricity of opposite sign to that at the base of the cloud above you. If you hear a lightning conductor hissing like that, it is doing its duty.

The Chairman: Ladies and gentlemen, as there is no more discussion, I will again thank Mr. Wood, on your behalf, and declare the meeting closed.

The meeting terminated at 9.50 p.m.

STUDENTS' SECTION.

(Report of Meeting held on 24th April, 1924.)

Mr. P. Fraser (*Associate Member*) exhibited various insulating materials and showed an insulation test by means of a potential transformer. The instrument for testing was comprised of two brass poses kept together with a spring, and when insulation was to be tested it was put between the two poses and the potential applied until it broke down.

After the meeting, by kind permission of the General Manager of the Power Station, Mr. P. Fraser took members through the Jeppe Sub-station, in which a very interesting tour was spent.

Mr. P. Fraser was thanked for giving a very interesting evening to the Students' Section and the meeting closed at 10 p.m.

South African Institute of Electrical Engineers

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Note.—All advertisements should reach the Secretary of the Institute not later than the 15th of the month for insertion in the ensuing number of the Journal. For further particulars apply to the Secretary of the Institute, P.O. Box 5907, Johannesburg.

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