The Mining Electrical Engineer.

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EDITED BY E. DINSDALE PHILLIPS.

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Greetings to all our many good friends:

A Merry Christmas and
A Happy New Year.

Competency by Examination.

Apart from and in addition to technical knowledge and experience, there are certain essential personal qualities which go to make a mining electrical engineer competent in the full sense of the word. These may be summarised briefly as:—

The sense of personal responsibility; there must be no blaming the "other man" whether he be workmate or manager, designer of the plant, organiser of routine in the pit, or buyer, or selector of lay-out plans and system. The electrical engineer in charge is the responsible individual.

The "wide-awake" faculty which precludes the chronic easy placidity that all is well whilst the wheels are turning; which demands the sagacious outlook for possible troubles, the "nose" for incipient weaknesses.

Ingenuity and an inventive faculty which can promptly and successfully devise safe emergency expedients and utilise fully the common means at hand for safeguard and for restoring security when trouble is, to him of keen foresight, obviously brewing or has already come.

Above all, he must never forget that his first and greatest consideration is the guardianship of life and limb; that his next great consideration is money.

This is merely to state very broadly some of the leading essential points of character inherent but developed by training. The simple citation given here will be traced through by the thoughtful intelligent reader into the many details involved; who, after continuing in his honest analysis, will perceive that the combination of a sound, healthful, sensitive constitution reinforced by systematic hard study, will alone ensure the acquisition of these essential points: and, even then, only when the individual is by his nature so built or compounded (for men have innate differences, let who will argue to the contrary) as to be susceptible to the development of these faculties.

Further consideration on these lines inevitably broaches the highly contentious theme of grade or status in regard to a man's usefulness; and the question which at once arises is whether the right type of man enters into mining electrical engineering. The ambitious workman sees in this electrical work something which is fascinating in that it is uncommon and special. He goes into it freely, though often blindly. There is not the slightest intention to cast any slur or disparagement upon the workman, but the duties of the mining electrical engineer are far outside the capacity of the workman.

There is much evidence to show that the right type of man does not seek mining electrical work. The Annual Reports of H.M. Electrical Inspector for Mines, and the Reports of the Examiner for the Annual Examinations of the Association of Mining Electrical Engineers, prove convincingly, year after year, that many men are placed in mining electrical positions who are not worthy of the highly responsible duties expected of them. Doubtless some of those men are so built as not to be capable of becoming proficient; but, unhappily, it would appear also that there are some who, perhaps for lack of incentive or other reasons either will not try, or have not the opportunity, to make themselves proficient.

This is a serious state of affairs because incompetence here directly introduces heavy risks to life and property, as well as considerable financial loss both in regard to maintenance and equipment costs and to the strangle-hold of perpetual waste in costs per ton output.

The obvious remedial measures are indicated by the nature of the defects. They are, concisely put, to provide adequate means of training and to encourage the right type of man by giving him the sweetening financial reward which is a fair return for his labour.

Last month, in these columns, we were prompted to protest against the seemingly deliberate rejection of the useful lessons given in the Reports of H.M. Electrical Inspector of Mines. In another part of this number we give particulars from the Report of the Chief Examiner for the Examinations of the Association of Mining Electrical Engineers which proclaims similar adverse criticism. As Professor Statham says in his Report, it is indeed regrettable that only thirty-six men a year should volunteer for these examinations; but it is very important to note also that he is all against lowering the standard of the tests to encourage a larger number of candidates. In view of the unsatisfactory state revealed by H.M. Electrical Inspector, all will agree with Professor Statham in his firm attitude that the A.M.E.E. Examinations shall continue to be of sufficiently high standard to guarantee that the successful candidate has thereby proved himself qualified to perform the duties of mining electrical engineer.

Whilst there is thus no question of reducing the standard of examination, we may express the doubt as to whether a reduction in that respect would have the effect of bringing any greater influx of entrants, for there are more men who rigidly refrain from submitting themselves to a voluntary test than are willing to undertake the systematic and somewhat exacting training to enter a non-compulsory contest.

The syllabus of the examinations as well as the questions set show that the A.M.E.E. Examinations are very well planned for their objective. We have no criticism to offer in that connection. It would, however, judging from the Examiner's Report, seem that some amplification of the method of examination could with advantage receive consideration by those responsible.

It is reported that very frequently the candidates are not well versed in the "three Rs" of elementary education. An inferior standard of spelling, grammar, composition, and draughtsmanship is always to be regretted and must count against a man; but we cannot agree that it should, at this present day, be accepted as a deciding factor in an examination of this kind. We do not say or infer that this weakness has ever been so accepted in these examinations; but we are of the opinion that the knowledge that his examination effort would be open to these blemishes is sufficient to deter many capable engineers, having the highly developed personal qualities mentioned in the beginning of these notes, from entering an all-written competition. Those men would, however, submit themselves to an oral examination and practical test, and would support and supplement their personal efforts with written answers to the best of their "educational" ability.

Furthermore, the inclusion of oral tests as a standard part of the examination for these certificates of competency would add greatly to their value. There is no need to discuss the acknowledged inadequacy of written examinations as a dependable test for industrial proficiency; it will be generally conceded that personal cross-examination and, where possible, practical tests are most desirable and useful in the accurate gauging of a man's industrial worth by "examination."

NEW BOOKS.

OVERHEAD POWER LINES: Elementary Design and Calculations. Captain W. Morecombe, R.E., B.Sc. (Eng.), A.M.I.E.E. Chapman & Hall, 11 Henrietta Street, Covent Garden, London, W.C. 2. Price 15s. nett.

TIN COMPANIES' POSITION.—W. H. Rickinson & Son, 3 Great Winchester Street, London Wall, London, E.C. 2. Price 2s. 6d. post free.

This, the tenth edition, is a financial and commercial guide to the world's tin industry. The position of every tin company, its capital and production, is reviewed to date. In the Preface it is shown that the outstanding feature of the tin industry during the first eight months of this year has been the heavy increase in consumption of the metal. The figures are both interesting and significant, and are shown in the following figures of world consumption: January-August, 1927, 91,206 tons; January-August, 1928, 100,782 tons; January-August, 1929, 110,568 tons.

Thus the tin consumption in the first eight months of both 1928 and 1929 has increased 10 per cent. on the consumption of the year before. These figures relate to approximately 90 per cent. of the world supply of the metal.

In consequence of the developments begun when the price of tin was at a high level some two or three years ago, and when much new capital was made available, production increased throughout 1928, and notably in the early months of 1929.. Nevertheless, the margin between production and consumption still remains relatively narrow. This is because at the prices which have been ruling, certain production has ceased or been curtailed. If this state of affairs continues, while the rate of growth in consumption is maintained, there must take place a serious diminution in the stocks which are requisite to the stability of the industry.

As regards supply, the basic factor is that tin is produced under greatly varying conditions. The most efficient, best equipped, electrically operated, modern dredges working in rich alluvial ground may produce tin at a cost of £100 a ton, or even less. On the other hand, the cost of lode mining may be as high as £250 a ton. Within this range are found all types of producers, and a certain amount of tin is won at every figure within these extremes.

HIGH VOLTAGE CABLES: Theory and Practice of their Design and Operation, by P. Dunsheath, O.B.E., M.A. (Cantab.), B.Sc.Engineering (Lond.), etc., Research and Technical Manager, W. T. Henley's Telegraph Works Co.; with a Foreword by Prof. W. C. Clinton, B.Sc.—London: Sir Isaac Pitman & Sons, Ltd., Parker Street, Kingsway, W.C.2. —Price 10s. 6d. nett.

This is essentially intended for consultants, engineers engaged in research at cable works, technical lecturers and students. It gives also a valuable summary of other published works as well as accounts of the author's original experimental researches.

THE PRACTICE OF ELECTRICAL WIRING by Donald Smeaton Munro, M.I.E.E., M.A.Min.E.E. (Third Revised and Enlarged Edition). London: The Electrical Review, 4 Ludgate Hill, E.C. 4. Price 4/6 nett.

This revised and enlarged edition of a text book which has for many years enjoyed the reputation of a standard work on its special subject is assured of its welcome. The section devoted to Wiring in Mines covers the general conditions in relation to distribution, earthing, protection of cables, trailing cables, methods of installation, maintenance, and statutory tests.

Methods of Exciting Field Magnets.

F. MAWSON.

(This is the eighth of a series of Articles intended more particularly to help Students and Junior Engineers: the preceding Article appeared in the October number.)

NEARLY all direct-current generators are made self-exciting, that is, some of the current from the armature is utilised to magnetise the pole pieces. This may be accomplished in three ways, series excitation, shunt excitation, and compound excitation.

Series Generators.

The method of series excitation is shown in Fig. 1 through the brushes + A and — A in series with the field exciting coils circuit S and the external resistance R. The connections should be made as in Fig. 1. With this method, the magnetising force and, consequently, the magnetic flux in the armature, varies with the current the machine is furnishing to the external circuit. When the armature is running at constant speed, the E. M. F. generated varies nearly as the current varies. This variation of E.M.F. is not usually desirable in a generator, since for most electrical services a constant voltage is required.

Shunt Generator.

In the shunt generator, Fig. 1 may be used with different connections, the field is connected as a shunt directly across the brushes, that is, the following connections being made + A to + R, — A to — R, + A to + S and — A to — S. The field is therefore in shunt, or parallel, with both the armature and the external circuit. Except when starting, the magnetising coil circuit is subject to the full difference of potential between the brushes + A and — A. Changes in the external circuit will therefore affect the proportion of current passing round the shunt circuit. With an increasing current flow in the external circuit (i.e., an increasing load on the machine) the potential difference at the brushes of the generator is reduced and, therefore, the field flux weakened. Thus the tendency of a shunt wound generator is for the voltage to fall with the rise of load to full output. A variable resistance should be connected in the shunt field circuit, so that the current flowing may be varied and the voltage of the machine adjusted to the requirements. This is a very useful machine when variable voltage is required.

When starting up a machine, there is usually sufficient residual magnetism to generate a small E.M.F. in the armature windings. A small current, therefore, flows round the field circuit, increasing the E.M.F. until the generator "builds up" its full field and delivers the full rated voltage.

Compound Excitation.

This is the most common and useful arrangement. It is a combination of the series and shunt methods just described. The connections of a compound field winding are shown in Fig. 2. If it is desired to maintain a constant voltage at the brushes for all values of the armature current, the generator should have compound windings in which the effect of the series and shunt windings are balanced throughout the output range of the machine.

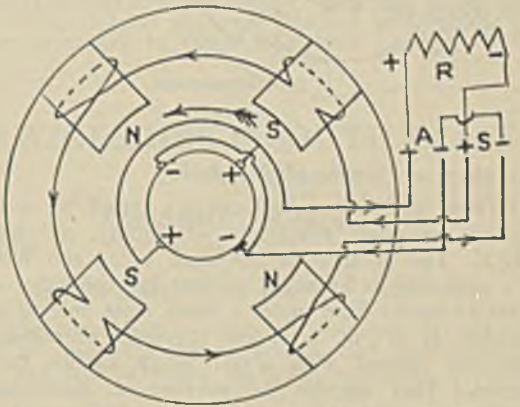


Fig. 1.

The shunt, or thin wire field winding, is connected to the brushes, that is, + A to + S and — A to — S for what is known as short shunt, that is, the shunt field is directly across the armature; and to — A and — M (as a long shunt, that is, the shunt is across the armature and the main or series field).

For regulation of the voltage a small variable resistance should be placed in the shunt circuit. The main field is connected as shown in Fig. 2.

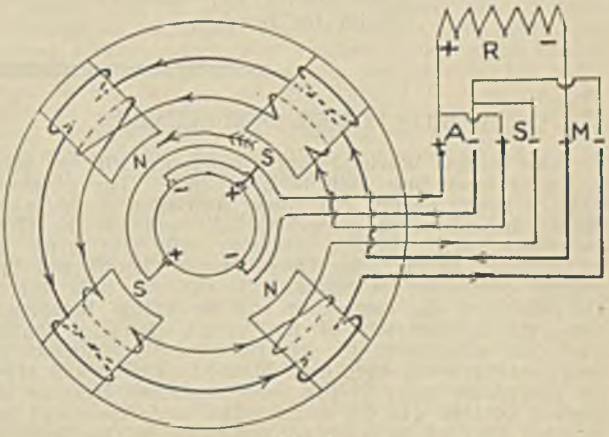


Fig. 2.

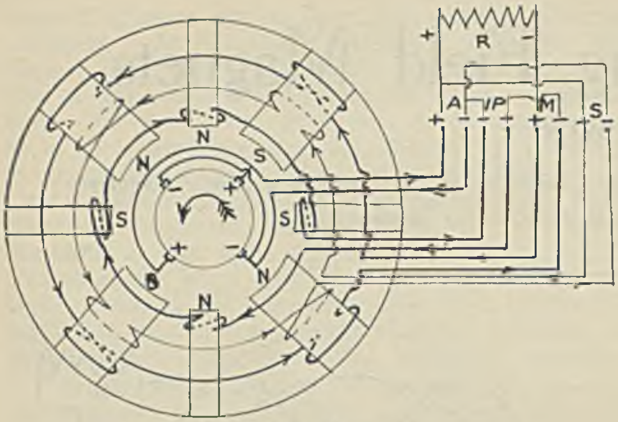


Fig. 3.

Interpoles or Commutating Poles.

These auxiliary pole-pieces are fitted to nearly all modern machines, generators or motors, as shown in Fig. 3. The polarity of the main poles and interpoles of a generator is arranged so that the conductor on the armature passes from under a south main pole to a north interpole as in Fig. 3. These interpoles or commutating poles are wound with a coil which carries the main current. They are for the purpose of improving commutation, so that the generator can work sparklessly at all loads within its rated range without any movement of the brushes backwards or forwards being necessary to suit the fluctuations of the load. The connections for short shunt should be made as shown in Fig. 3. If variable voltage is required a variable resistance should be coupled in the shunt circuit for this purpose.

The E.M.F. of a Generator.

The general formula for the E.M.F. of a generator is

$$\text{The average pressure in volts} = \frac{\text{Ø} Z n}{10^8} \text{ volts}$$

where Ø = the number of lines of force cut by each conductor in the armature per revolution.

n = the number of revolutions per second.

Z = the number of conductors in series with the brushes.

Ø varies as the ampere turns, that is, the current multiplied by the number of turns on the pole pieces. It follows, therefore, that with an increase of current in the field coils, an increase takes place in the generated E.M.F.

The flux or number of lines of force is dependent upon (a) the permeability or specific magnetic conductivity of the material of the pole pieces and the core of the armature; (b) upon the area of the pole pieces; and (c) the length of the path the lines of force have to traverse.

The Losses in a Generator.

Generator Losses may be classified under four heads, (1) the mechanical losses, friction and windage in the machine; (2) Losses in Field Excitation; (3) Losses in the Iron of the pole pieces and armature; (4) Copper Losses in the armature.

Friction takes place between the shaft and the bearings (this is very small in the modern machine) and between the brushes and the commutator. Windage, or friction of the air surrounding the rapidly revolving armature, while it is a loss is extremely beneficial in that it helps to reduce the temperature rise of the machine caused by the heating effect of the current passing through the windings.

The loss in the field excitation is entailed by sending a current through the resistance of the field coils and is dissipated in heat. The loss can be easily calculated from the current and the resistance of the wires. The loss in watts is equal to the current squared, multiplied by the resistance; the resistance is a variable quantity which increases as the temperature of the coils rises.

The iron losses are due to eddy currents and hysteresis in the iron of the armature core, this is reduced by the use of thin sheet stampings, laminations, insulated from one another. The hysteresis is due to the reversals in direction or alternations of the magnetic field.

The copper losses in the armature are heating losses due to the current flowing through the resistance of the armature windings.

Of the total losses in a generator, the friction, field excitation, and iron losses, are termed constant losses, as they are approximately the same whatever may be the load or current delivered by the machine, so long as it runs at normal voltage and speed. The loss in the armature winding is nil when no current is delivered, increasing with the square of the current delivered.

WORLD POWER CONFERENCE.

The Second World Power Conference will be held in Berlin from June 16th to 25th, 1930. The development of power supply and power utilisation is the main subject around which discussion will centre at the 1930 conference. The opening ceremony will take place in the premises of the State Opera House (Kroll) and the general conference meetings will also be held there. The offices of the conference will be at the Ingenieurhaus, the headquarters of the Verein Deutsche Ingenieure. In addition to the general sessions, a number of social arrangements have been planned. Before and after the conference visits to the most important German industrial centres will be made. The conference will be presided over by an honorary committee, at the head of which is His Excellency Staatsrat Dr. Oskar von Miller, the pioneer of electricity supply and founder of the German Museum. The honorary committee is composed of representatives of the German Federal and State Governments, municipal corporations, the leaders of German industry, and representatives of German science of international reputation.

PERSONAL.

Mr. G. R. T. Taylor has resigned his appointment as Deputy Chairman of Vickers Limited, but retains his seat on the Board. Mr. G. G. Sim, C.S.I., C.I.E., has been appointed Deputy Chairman in his place. Mr. J. Reid Young, C.A., has been appointed Secretary to the Company in place of Mr. Sim.

Proceedings of the Association of Mining Electrical Engineers.

DONCASTER SUB-BRANCH.

Chairman's Address.

C. WHITEHOUSE.

(*Meeting held October 26th,* 1929.)

When this Association was inaugurated 21 years ago Doncaster probably had two or three members. Since then the increase of membership in this district has been slow, but never-the-less sure. The meetings of the Yorkshire Branch are held in various centres which of course is quite a right system, but there was always the difficulty that a large proportion of members from this part found it impossible to attend the meetings regularly, as it often meant the whole of Saturday afternoon and evening being given up for a 1½ hours' meeting. However, the great necessity was acted upon by Mr. Bleach, and the result was the Doncaster Sub-Branch was formed and received the sanction and blessing of the A.M.E.E. Council. This advance immediately brought new members, apart from those who transferred from the parent Branch, with the result that there are at present about 60 members of the Sub-Branch which is a very satisfactory number. Mr. Bleach was elected our first Chairman, and Mr. Morris, the Secretary. Mr. Morris is still carrying on, with the assistance of Mr. Bunny, and great credit is due to Mr. Bleach and Mr Morris for the way they carried through the first and most difficult period of our history. Mr. Wadeson was our Chairman last year, and he not only carried out his duties as Chairman with great distinction, but he gave some very interesting addresses; it was sincerely to be hoped that he would continue his helpful work in a similar way.

With regard to the programme for the Session, it does not matter greatly whether contributions are in the shape of papers, addresses or discussions, so long as we get them. Things that may seem of little interest to one's self often prove to be of outstanding value to others, therefore, any member with notes of interest should broadcast them at the meetings. Then again any member with a difficult problem to face should bring it here for discussion; he will benefit, as well as his fellow members. There is that little proverb " If you have knowledge let others benefit by it", which might well be the motto of the Association.

Any member or associate may qualify for the Association Certificates, and I would strongly advise them, particularly the younger members, to prepare themselves and sit for these examinations. The Certificate issued by the Association is a proof of training and a valuable asset to any member; moreover, it may be in the near future recognised by the Home Office. In any case there is no doubt that the Colliery Electrical Engineer henceforth must be able to show some certificate of qualification, and he could not have a better than the first-class certificate of the Association of Mining Electrical Engineers. I hope at the next Examination to see that quite a number of our Branch members have presented themselves and been successful.

With regard to visits during the Summer months, I would like to mention that last Session we had two or three very successful and interesting visits, and our thanks are due to the firms whose works and pits we visited. We hope to be able to arrange similar visits next Summer, and hope members will endeavour to take part in these, as they are most interesting and instructive. Visits are perhaps rather like a busman's holiday, but even the busman picks up quite a lot when riding on top of the bus, instead of driving same.

Mr. BLEACH proposed a hearty vote of thanks to the Chairman.

Mr. H. MORRIS seconded the vote, and, Mr. Whitehouse having suitably acknowledged the compliment, the company proceeded to enjoy a Smoking Concert.

WARWICKSHIRE & SOUTH STAFFS. BRANCH.

Presidential Address.

A. HULME.

(*Meeting held September 26th,* 1929.)

In the course of his inaugural address Mr. Hulme thanked the members for the honour they had conferred on him and said he would earnestly endeavour to justify his election as President of the Branch. He had not prepared anything in the nature of a technical address but would confine himself to a few observations regarding the Association, and more particularly would he speak to the younger and new members. It was very important that all members should be conversant with the principle objects of the Association, as clearly and definitely set out in the Articles of the Association.

He hoped that the younger members would take advantages of the opportunities afforded them and submit their experiences and personal observations in the form of Papers and by taking part in the discussions. He would particularly impress upon young members, who were often nervous in regard to speaking at meetings, that they would receive the very greatest encouragement and help. The older and more experienced members were always prepared to encourage the beginner in every way possible. After all, everyone must make a start and those experiences which appeared difficult to the junior member would often be found to have been met and overcome by those of wider experience. He himself had joined this Branch during its first year, and so had been able to watch its successful progress. The members' deliberations had been very helpful in the way of developing the use of electricity in mines, and in directing the improvements in such apparatus as switchgear control, motors, and cables for mining service, which now reached a very much higher standard of reliability than was the case in the early days of the Branch; he felt justified in claiming that such an advanced degree of development was in no small measure due to the efforts of the Association. He felt considerable gratification in his long association with so successful an organisation.

With the rapid development and increasing importance of power installations in coal mines, electrical motive power being the most efficient would inevitably displace other forms of power; as well as for the great reason that its flexibility lends itself readily applicable to all power requirements. With the increasing need for electrical machinery at the coal face, the duties and responsibilities of the electrical engineer and staff were daily becoming more complicated and strenuous. It thus devolved upon the younger members to obtain sufficient knowledge, to enable them to perform their duties with confidence from an efficient and safety point of view in the control and maintenance of the mining electrical plant which has become a vital part of the colliery industry.

Referring to the matter of Certificates, Mr. Hulme said they could all be assured that the aim of the Association had always been to secure fitting recognition of the mining electrical engineer, and that the Association moreover was pressing more effectively than ever its efforts in that direction.

He looked forward to this session being one of the most useful because there were several very important papers to be read at the meetings, and he hoped that all members would do their best to put in attendance and take active part in the discussions.

In conclusion, Mr. Hulme expressed the thanks of the members to Mr. F. J. Hopley for his valuable services as President of the Branch during the last session.

The motion was cordially supported by Mr. S. H. Morris and Mr. J. R. English, and suitably acknowledged by Mr. Hopley.

WEST OF SCOTLAND BRANCH.

A meeting of this Branch was held in the Royal Technical College, Glasgow, on Wednesday, 16th October last. Mr. G. N. Holmes, Branch President, occupied the Chair. After the Minutes of the previous meeting had been read and apologies for absence intimated from Messrs. Gibb, Hart, Beckett, and McKillop, the following applications for membership which had been approved by the Branch Council were passed: Members—Messrs. John Lindsay, Dan Scott, and John Smith; Associate—Mr. Joseph Hastings.

Thereafter Mr. Mitchell read the following Paper

Ⓟ The Operation and Maintenance of High Lift Mining Pumps.

WILLIAM MITCHELL.

From a mining point of view water has been aptly termed "The Silent Enemy" and history credits it with many victories. Even when it is seemingly overcome and subdued by its adversary the pump, it is ever ready to burst the bonds and regain freedom. Exhaustion of the shallower seams, extension of the workings tc greater and greater distances from the shaft, increasing outputs, and decreasing margin of profits, have all played their part in compelling the mining engineer to modify, improve and cheapen his methods of dealing with the water which constitutes not only an embarrassment to working, but in almost every case a dead and unremunerative charge upon his output. The purpose of this paper, however, is to discuss some of the troubles that afflict high lift mining pumps, and to express the author's views on some of the defects pertaining to ineffective control.

HIGH LIFT PUMPS.

Modern high lift mining pumps can be grouped under two heads, namely, the Reciprocating Pump and the Rotary Pump. Of these two types the horizontal three-throw ram pump and the multi-stage turbine pump hold the field. Either type of pump has its own individual merits over the other and the respective advantages and demerits may be classified as follows :—

Advantages of High Lift Ram Pumps.

(1) Considered to be higher in efficiency than turbine pumps and, therefore,
(2) Power costs will be lower.
(3) Working parts are more readily accessible and the wear is easier seen and rectified than with turbine pumps.
(4) A ram pump will operate under conditions which would be difficult with a turbine pump.

Demerits of High Lift Ram Pumps.

(1) Larger floor space required than with turbine pumps.
(2) First cost is higher.
(3) Lower power factor owing to the general tendency of low speed motors.
(4) Water hammer is of common occurrence.
(5) Cost of packing and lubrication higher.
(6) Frequent examination of valves necessary.

Advantages of High Lift Turbine Pumps.

(1) Smaller floor space required, consequently the cost of excavation is less.
(2) Lower first cost.
(3) Absence of water hammer.
(4) Lubrication and packing costs low.
(5) Higher power factor owing to use of high speed motors.

Demerits of High Lift Turbine Pumps.

(1) Lower efficiency than a ram pump, consequently
(2) Power costs will be higher.
(3) Working parts not readily accessible.
(4) Gritty water will cause excessive wear, making frequent adjustments necessary.
(5) Very sensitive to air leakage.

OPERATING TROUBLES ON THREE-THROW RAM PUMPS.

Water Hammer.

Of all the troubles that afflict the three-throw pump, water hammer is the most prevalent. It may be set up from any of the following causes.

(1) Partially choked suction.
(2) Defective pump valves.
(3) Pump operating on two rams only.
(4) Air leakage in suction main.

At the first sign of water hammer, the pump should be stopped and the defect rectified. If allowed to continue a joint may be blown out or some part of the pump or delivery column damaged; the part damaged is usually a bend or reflux valve, parts that are costly and generally take some time to replace. At the same time there is the additional danger of flooding the engine room and the resultant damage to the electrical gear, the motor as a rule being the chief sufferer. A spring loaded relief valve if placed on the discharge side of the reflux valve will safeguard the pump and delivery column from excessive shock, care being taken that the valve is not made ineffective by setting the spring too tightly.

Partially Choked Suction.

This trouble occurs if the pump is allowed to snore, the floating debris being drawn into the strainer and getting wedged in the holes, or mud being allowed to accumulate in the lodgment until it covers the strainer. The remedy in either case is obvious. On a ram pump the trouble is indicated by excessive noise at the cranks and crossheads combined with water hammer as each ram returns into a half empty casing. On a turbine pump the effect is to limit the quantity of water delivered, and if the delivery valve is not closed in proportion, the pump will start hunting, i.e. losing and catching the water. The resulting surges set up may damage the balance valve and thrust bearing. Turbine pumps should not be used when cleaning the lodgment, as the mud will choke all sealing pipes and water jackets, also causing rapid wear of impellers and balance valve. This duty is better undertaken by a ram pump, where the wear comes on the packing, which can be easily renewed. It is not advisable, unless in case of emergency, to operate a high lift ram pump on two rams. The out-of-balance stresses combined with the resultant water hammer make it a dangerous experiment.

Valve Defects.

Trouble may arise here through a variety of causes: springs and valves breaking, rubber discs cut up, or valve seats working loose. Persistent troubles with valves and springs breaking, points to excessive lift. While theoretically one-fourth the diameter of the valve is the correct lift for a single beat valve, it will generally be found advisable to reduce this, as the shock when the valve strikes the seat may be objectionable with full lift.

A loose valve seat is one of the worst defects that can happen on a reciprocating pump. If a delivery seat gets loose, it follows the valve and obstructs the passage of the water into the delivery column, creating exceptionally high pressure which may burst the valve or ram casings. A loose suction seat prevents the water from following the ram on the suction stroke, the ram returning idle on the delivery stroke, thus throwing the pump out of balance. Both of these defects set up violent water hammer, and a serious breakdown may result if immediate action is not taken. The valve seats of all high lift reciprocating pumps should be secured in position either by screwing, by being pinned, or held in by an extension of the cover. The method of fastening will depend on the type of valve employed. Easy access to valves and the use of bolts in preference to studs are features of good design.

Air Leakage in Ram Pump.

While not so sensitive to air as a turbine pump the volumetric efficiency of a ram pump is more or less affected by the amount of leakage taking place. The ram packing glands and the joints in the suction main being the weak spots. The condition of the ram packing can be seen at a glance as any deficiency here shews up on the discharge stroke. The joints on the suction main can be tested by allowing pressure from the delivery column through the bye-pass into the suction pipe, each joint being examined while under pressure.

Air Vessels.

Air vessels on the suction side of reciprocating pumps reduce the shock of suction valves closing and also maintain a uniform velocity of flow between the lodgment and the air vessel. Delivery air vessels should be placed over the discharge valves so as to absorb all shock in the pump; if placed on the delivery column at some distance from the pump, and bends intervene, their function is limited to equalising the pressure and reducing the shock in the delivery pipe.

When dealing with high pressures, air vessels soon become water-logged and useless if not kept supplied with air. A small air pump is usually fitted for this purpose Snifter valves are sometimes fitted to admit air under the delivery valves of the pump for the purpose of replenishing the delivery air vessel. But as air admitted in this fashion reduces the pumping efficiency, their use is not advisable. All air vessels should be fitted with gauge glasses so that the condition of the vessel can be seen at a glance.

Gearing.

With the advent of the flexible coupling gear troubles have practically vanished. Broken teeth, bent shafts, and cracked motor and frames, are now of rare occurrence. It would be safe to say that 50% of the electrical breakdowns on heavy reciprocating pump motors could at one time be attributed to the former practice of fitting a steel or cast iron pinion on the motor shaft and gearing it direct to the spur wheel on the second motion shaft. The vibration set up very often loosened the laminations of the motor, with disastrous results to the windings or eased the bearings to such an extent as to allow the rotor or armature to foul the poles. While rawhide pinions overcame the trouble to a certain extent the large sizes and frequent renewals made them a somewhat expensive luxury. A flexible coupling of the claw type with renewable packing between the claws will absorb all shock transmitted from the pump gears. It will also safeguard the gearing from the effects of any mismanagement of the starting switches. The cost of renewals is exceedingly low if the alignment of the coupling is not disturbed.

Joints and Jointing.

Troublesome joints can generally be traced to one or more of the following causes:

1. Flange faces not parallel.
2. Insufficient number of bolts in flanges to pull joint up tight.
3. Flanges have plain faces instead of spigot and faucet.
4. Vibration from pump straining the joints.

(1) If it be inconvenient to alter the pipe line a bevel joint may be put in. This should be faced up in the lathe and a spigot and faucet turned to correspond with the pipe flanges, care being taken when inserting the bevel that it is placed in the correct position between the flanges.

(2 & 3) The use of any old piping that happened to be lying about is the usual cause of these defects and little can be done here, except to scrap the faulty stuff and install suitable piping.

(4) This trouble only occurs with reciprocating pumps—the foundation bolts may be loose or the ram casings may be working on the sole plate. The casings are usually secured by fitted bolts and dowel pins. If the pins have worked at all easy they should be renewed as very little movement here sets up a grinding action on all joints between the casing and the delivery column, destroying them in a very short period.

There is a big variety of jointing material to select from but rubber insertion makes a good joint for water pipes. The joint rings should be cut to the correct size and put on dry. Some make it a practice to coat the rings with grease or tallow but this has a deteriorating effect on rubber and causes the joints to perish.

Foot Valves.

One of the troubles experienced with foot valves is their liability to stick and remain open, a serious matter when dealing with a turbine pump. Unless fitted with an air extractor it will be impossible to prime the pump if the foot valve is open. This defect is generally discovered at the wrong time, usually at the beginning of a pumping shift, when the water level may be twenty or thirty feet above the top of the foot valve. In an emergency the pipe line could be disconnected at the water level and a short pipe with a spare foot valve fitted on; thus gaining time to withdraw the defective foot valve and make the necessary repairs. A better plan is to fit a clack valve into the pipe line at high water level, and keep out the clack for normal working. When the foot valve failed, it would only be necessary to take off the cover of the clack, and insert the valve. The pump can then be primed and started without any difficulty. The defective foot valve can then be got at when the water is low, without disconnecting any of the pipe line, as handling pipes of heavy section, under the conditions that generally prevail at this end of the plant, is a job not to be lightly undertaken.

Lubrication.

On reciprocating pumps the crank shaft bearings and connecting rod ends give little trouble if fitted with substantial grease cups of the tell-tale pattern, provided the grease is kept free from grit. The feed can be regulated by adjusting a screw inside the cup.

The second motion shaft and motor bearings are usually ring oiled. Split oil rings should be avoided if possible: while they may be very convenient to assemble, they are liable to open and ruin a bearing before the defect is noticed. Every ring oiled bearing should be fitted with two rings. In the event of one sticking the other would still function. Ball and roller bearings are now standard practice on motors and give every satisfaction. The author used to hesitate before putting a motor with ball bearings on a gear drive but experience has proved their reliability. They do not suffer from neglect of the oil-can, as one filling of suitable grease will usually last for many months. Owing to the exceptionally fine limits adopted in the machining of these bearings the air gap of the motor is uniform and remains constant.

The bearings on turbine pumps, owing to the higher speeds involved, are liable to give more trouble; the main bearings being usually ring oiled; if the rings are sluggish the oil wells should be cleaned out and filled with fresh oil. At the same time the rings should be examined for circularity; any want of truth will cause them to be erratic in action. The thrust bearing, if of the Michel type, will be oil immersed. A light machine oil should be used for this bearing; any attempt to use a heavy oil will result in increased temperature.

HIGH-LIFT TURBINE PUMPS.

It is only within recent years that the multi-stage turbine pump has come to the fore as a serious rival to the three-throw pump. It has, however, made rapid headway and bids fair to oust its older companion from premier position. Occupying only one-fourth of the space of a reciprocating pump of similar capacity, and its comparative freedom from water hammer with all the attendant evils, would make it seem to be the ideal mining pump. Unfortunately, the turbine pump is not without blemish, as quite a number of weak spots show up under working conditions.

Air Leakage.

The most frequent source of trouble is air leakage, a very slight leakage being fatal to pumping operations. The pump will merely churn the water in the casing, and if the pump is left unattended the water will evaporate, leaving the shaft and impellers dry, considerable wear if not actual seizure may then take place. The suction packing gland is sometimes to blame for this state of affairs, the sealing pipe from the first stage to the centre of the gland may be choked. This pipe should be taken off and cleaned, the passage into the gland should be examined at the same time. The packing in the box can be withdrawn and the spacing rings seen to, as they sometimes get blocked up with pieces of packing. The joints in the suction column can be examined and tested as already indicated for ram pumps.

Air Lock.

The suction pipe should rise in a straight line from the lodgment to the pump, if undulating, air pockets will be formed. If a bend is unavoidable a small pet cock can be fitted at the highest point to blow off any air that may be trapped. This will only be necessary if the level of the water is allowed to become so low that air enters the strainer. Under ordinary conditions the water level should not be taken any lower than two feet above the strainer as whirlpool action is likely to be set up.

Balance Valves and Thrust Bearings.

All the multi-stage turbine pumps that the author has had to deal with have single entry impellers, consequently considerable end thrust takes place. This is overcome by means of a balance valve. Some makers fit a thrust bearing of the Michel type in addition to the balance valve. As the thrust bearing is a rigid body, and the film of water between the balance valve faces a variable one, it is sometimes a difficult matter to get the two properly adjusted. If the water is gritty, it plays havoc with the balancer, causing frequent adjustments to be necessary. The author has adopted the following method: machine the balance valve faces and adjust in position, pull the valve faces together, and set the Michel bearing with the valve plate hard against the pads. When the pump is working the thrust bearing faces will be clear by the thickness of the water film at the balance valve. As wear takes place the load will be gradually transferred to the thrust bearing. The temperature of the oil in this bearing being a good index to the condition of the balance valve.

In these few notes the author has endeavoured to give a concise account of the troubles met with in the operation and maintenance of high lift pumps and to express his views on how best to mitigate these troubles to obtain and ensure regular and efficient operation.

Discussion.

Mr. G. N. HOLMES (in the Chair) expressed indebtedness to Mr. Mitchell for his excellent paper. The author had not shown whether he favoured the ram pump or he favoured the rotary pump. Apparently both types have their particular uses, though Mr. Mitchell had not made it quite clear in which case he would use either the one or the other.

Mr. A. DIXON.—In his Paper Mr. Mitchell referred to water hammer, about which there does not seem to be much information. One thing the author did not mention was, when water hammer does occur, how could the cause of it be detected? Mr. Mitchell omitted one factor that comes in very largely when determining whether to use ram or turbine pumps, and that is the head-quantity ratio.

Mr. Dixon then referred to some centrifugal pumps which are now being put into operation for drainage and reclaiming land in the Wash district. The delivery column of that installation is about 8 feet 6 inches in diameter. Though, of course, the pumps only lift a few feet, they are claimed to be the biggest ever made, being of about 2,000 or 3,000 horse power.

Mr. Mitchell had mentioned putting gauge glasses on the air vessels. That seemed alright up to a point, but is it practicable with high heads and what would happen if water hammer set in? Would the gauge glasses last very long?

Mr. Dixon said he was entirely in agreement with Mr. Mitchell on the question of flexible couplings and the methods of driving, especially on the ram pumps, but he would go a stage further; he considered it advisable to avoid altogether the overhung pinions which are so often used on those pumps. By putting in outboard bearings a great many of the electrical troubles were eliminated: very often the motor breaks down and the blame is put on to the electrical end when it is really altogether due to vibration.

He, Mr. Dixon, had found Mr. Mitchell's paper full of information of practical value and when it appeared in the Journal it would be read with great interest by the practical men of the Association.

Mr. MITCHELL.—With regard to the question of detecting water hammer, it is like every other pump trouble, it is necessary to get round about the pump and see where the trouble is. It is generally possible to detect whether the trouble is in the valves by listening to the valves and if there should happen to be a loose seat it will be detected right away. The pump generally stops itself; there is no question about that, the overload is so great that it trips the switches. If it is a leakage, a casual glance over the pipes will generally get the trouble. Then with regard to the point about the gauge glasses on air vessels, there is no difficulty: if the bore of the glass be small enough it will withstand enormous pressure: so far as water hammer is concerned it would be of little account to break a glass or two, but the chances are that something else much more important would break before the glass.

As to the other question about flexible couplings, the use of overhung pinions can be avoided: most of the manufacturers now put a flexible coupling between the gear and the motor.

Referring to the use of raw hide pinions, the pitches were generally so great, something like 2¼ or 2½, with a very high head, that the cost of the raw hide would be something abnormal and Mr. Mitchell had avoided that cost by fitting flexible couplings. The fitting of the claw type of coupling had done away with all that trouble; it was now only a case of the minor expense of renewing the packing between the claws.

Mr. D. BAIRD said that, fortunately, the colliery in which he was interested was not much troubled with water. There was not a great deal of pumping to be done; but he knew that the pumps, turbine or ram, were troublesome in many pits. In the case of a sinking dook where there is a natural growth of water, and that water has to be got out of the face to allow the colliers to work, a turbine or centrifugal pump would be of no use; it required a ram pump as the suction continually drew air.

Then again, in that type of pump that works at the coal face, springs in the valves were sometimes more a hindrance than a help, although the springs help the efficiency of the pump. There was a great deal of trouble due to pump valves being held up by small pieces of coal. If there were no springs the valves would close slower and were not held up so readily by the particles of coal.

Mr. Baird said he was sorry Mr. Mitchell had not brought out the point that both types of pump, with certain kinds of mine water were a continual source of trouble. He, the speaker, would imagine that the turbine pump would be much more troublesome than the ram pump as the casings and impellers were abraded or corroded away before the trouble was noticed and they were difficult and expensive to renew. Perhaps Mr. Mitchell could bring out that point and say whether he had had any experience of waters containing a great deal of acid, etc., and what remedies he would recommend in such cases.

Mr. MITCHELL replied that, fortunately, he had not had to cope with waters containing acid or other deleterious matter to the extent described by Mr. Baird. Referring to the question of a suitable pump for a sinking dook, it was not one for the use of a turbine pump unless a standby lodgment was provided and the water pumped out in periods.

With regard to putting springs on valves, he had a notable experience with a ram pump. The valves were all tight—they were actually so tight that whenever the pump was on the snore and the loose air was drawn up, the pump refused to lift; the air got locked between the two valves and it was actually necessary to file a groove on the discharge valve so that when the pump ceased to lift, it could prime itself. Usually a pump refuses to pump or at least loses a good deal of its efficiency owing to the valves being very badly pitted or worn, but in this case the valves were too tight and a leakage groove had to be cut in them to allow the water to trickle down between the two valves and so keep the pump primed.

Mr. HOWATT.—Mr. Mitchell mentioned that in putting up the balance plate on a turbine pump that he screwed it tight so that the thrust was clear and no more. Does he mean that a turbine pump is working the surplus water between the faces of the balance plate releases all thrust of the thrust bearing?

Mr. MITCHELL.—Yes, that is correct. When in touch with the manufacturers of a particular type of turbine pump, who fit a Michel thrust bearing on their pump, that was one of the questions brought up. He, Mr. Mitchell, told them it was difficult to adjust the thrust bearing to agree with the balance valve and they instructed that the thrust bearing should be clear altogether. Its function was more a warning; it was there as a guard. Whenever the balance valve was worn to such an extent that the thrust bearing was taking the whole thrust it was time for the balancer to be adjusted. That was what the makers told him, and that was why he had adopted that method. When the balance valves were being machined up, put the faces hard together and then put the plate up against the bed. The result was that the bearing would be clear by the thickness of the film and as the load gradually came on the thrust bearing would gradually shear up to the face.

Mr. HERBERT SMITH, commenting generally on the Paper said it was of the type which merited criticism, if for no other reason than to give the writer of the paper an opportunity of amplifying his subject matter in reply. Thus the first criticism amounted to a complaint that Mr. Mitchell's paper was a little too short. The title of the paper showed it to be concerning the operating and maintenance of high lift mining pumps, but it was not clear whether that applied only to clearing the mine of water, or to pumping plant necessary for the equipment of the colliery. Would Mr. Mitchell describe any failures he had had and how he dealt with them.

Mr. Smith said his experience had probably been more with centrifugal pumps; failures to get them started on occasions had often lasted over days and the troubles had been so small when eventually found that it was quite astonishing. In this connection he would mention the case of a diameter of a suction pipe that was larger than the branch of the pump. A taper pipe was necessary, and it was placed in a horizontal position, leaving an air pocket. Of course, the taper pipe should have been placed vertically. Then there was another case where they were pumping from machinery on the pithead. The tendency had been to allow the discharge to flow freely away, and that proved a failure because the pump must have some head against it. He wondered whether Mr. Mitchell could tell of failures of a similar nature which he knew of and how they had been overcome.

Mr. MITCHELL replied that he could give several illustrations of failures in turbine pumps. In one case they fought for three days with a belt-driven turbine pump, not a very high head, something like 80 feet, and finally discovered that the belt was too slack. Nobody ever thought of applying a speedometer to the pump to see whether it was going at the proper speed or not. Another failure with a turbine pump was when making some alterations to the piping. For four or five hours attempts were made to get the pump started up; it seemed to take the load and then lost it; at the end of that time the blacksmith mentioned that he had put a bag in the pipe when he was flanging it, and the bag was found still rammed hard into it. That was the trouble. He could give many examples of that particular type of trouble.

Referring to the question of head, Mr. Mitchell said he believed someone mentioned starting up a pump without a head: if the switchgear was not effective, that would result in burning out the motor. The motor overload would be such that it would either pull up or be burnt out.

The CHAIRMAN in concluding the discussion and thanking the author, said he agreed with Mr. Smith the paper was really too short. He had thoroughly enjoyed it and felt, by the way Mr. Mitchell had handled the subject, that he could have gone further.

KENT SUB-BRANCH.

Electricity.

A. R. COOPER.

(*Paper read 2nd November,* 1929.)

The reason for adopting the word "Electricity" as the title of this paper is not that the author believed he could do justice to so comprehensive a title but rather because his intention was to approach the subject from what is probably a rather unfamiliar standpoint. Instead of describing in laborious detail the behaviour of electrical machinery or some other phase of electrical practice with which most members are familiar, he proposed to attempt to illustrate the place which electricity holds in the general scheme of things.

One of the most recent scientific discoveries shows that all material is composed of electricity, and if it be possible to form some physical conception of what this really means, it should enable us to consider the more complex electrical problems with greater facility.

The investigations may, therefore, begin by splitting up, therorectically, a portion of any substance: for instance, a pinch of salt. If we could split up a pinch of salt into four smaller portions we should, quite naturally, have four very small portions of salt, and if now we took one of these very small portions of salt, and divided that into four, we should still be dealing in terms of salt as we were in the first instance, but if we had the ability to continue subdividing our portion of salt to the minutest limit we should eventually reach a stage at which our subdivisions would have to cease if we wished to continue dealing in terms of salt. In other words we should be left with the smallest portion of salt which could stand alone, i.e., what we call a molecule of salt. This division may be likened to the subdivision of a brick wall in which eventually the stage is reached at which we are left with a single brick, and can go no further unless we wish to split up the brick itself into its constituent parts. Similarly, we can go no further with the subdivision of our molecule of salt unless we split it up into its constituent parts, but we find that so soon as we do this we are dealing with different materials. The molecule of salt vanishes and we have left in its place two atoms, an atom of Sodium, which is a metal, and an atom of Chlorine, which is a poisonous gas, and neither of these atoms bears the slightest resemblance to the salt with which we commenced.

Every material known can be split up into its molecules in this manner, and every molecule can be split up into its atoms, but whilst there are as many different kinds of molecules as there are different substances, there is only a definite limited number of atoms. Altogether there are about 90 different atoms and, just as the vast field of literature is composed of different arrangements of the twenty-six letters of the alphabet, so every substance in the material world consists of different arrangements of this limited number of atoms. From the foregoing it will be seen that we can take any substance and by splitting it up to a sufficient degree we can find out which, and how many, of our 90 atoms go to its construction. It is only a short time ago since atoms were considered to be basic units in the structure of matter which could be subdivided no further, but electrical science has succeeded in showing us that even the atoms are built according to a definite plan and that they react or combine with each other according to simple familiar laws.

It will probably help at this point if we consider the structure of one of the simplest atoms, say an atom of Hydrogen, and endeavour to visualise what it really is. An atom of Hydrogen then, consists of what we call a solar system, and just as in our own solar system the earth spins round the sun, so in the Hydrogen atom we have a centre core round which a particle spins in an orbit or path at an incredibly high velocity. To form some conception of this arrangement, consider the spokes of a rapidly rotating flywheel. Although we know that there are free spaces between the individual spokes, the moving masses present all the characteristics of a solid wheel. In a similar manner we must visualise the Hydrogen atom as a solid particle produced by rotating units. Now it has been shown that the centre core is really a charge, or we might say a particle of positive electricity, and that the outer or rotating particle is a particle of negative electricity, so that the Hydrogen atom consists of nothing but particles of positive and negative electricity rotating round each other. Similarly we can show that an atom of Helium has a centre core composed of four particles of positive and two particles of negative electricity with two particles of negative electricity rotating round it, and so we could go on with the other atoms, explaining their structure as an arrangement of positive and negative particles of electricity. We see then that the only difference between an atom of Oxygen and, say, an atom of Carbon, is that the positive and negative particles of electricity of which they are formed are arranged in different ways.

Having reached this stage in our investigations we can see that, as all matter is composed of molecules, all molecules are composed of atoms, and all atoms are composed of different combinations of positive and negative particles of electricity, that all matter is composed of electricity.

Considering again the structure of the atom, it is easy to see that if an atom is composed of more positive units of electricity than negative ones, that the atom will bear a positive charge and *vice versa.* If therefore we arrange to put our atoms under the influence of positive and negative poles, those atoms having a positive charge will tend to collect on the negative pole, whilst those bearing a negative charge will collect on the positive pole. For instance, if we place positive and negative poles in a solution of Lead Acetate, the atoms of Lead, which bear a positive charge, will be attracted by, and will collect on, the negative pole.

If we remove electrons from a body by rubbing it, this body will bear a positive charge and will attract all other bodies which are not positively charged. This is the reason why a piece of brown paper when warmed and brushed, will adhere to a wall or any other similar body until its acquired charge has been dissipated by absorbing or giving out electrons.

If we place two electrodes in a column of smoke and raise them to different potentials, one electrode is crowded with electrons whilst the other is anxious to acquire them. Those particles of air which are passing the negative electrode collect electrons from it and are thus attracted by the positive pole. In this manner electrons are attached to all the sooty particles forming the smoke and they are attracted to the positive pole where they collect in the form of a sooty deposit which can easily be removed. This is known as the electrostatic method of smoke prevention and is coming largely to the fore in many branches of engineering.

Another field in which the electrical charge on the atom is made use of is that in which we use electricity for settling out what are known as Colloids. Many common liquids such as milk, starch, clayey water and rubber latex, practically all gelatinous liquids in fact, are colloids, and the peculiar feature about them all is that the molecules which are not in combination will not settle out under the influence of gravity as we should expect them to do. The reason for this is that all the molecules bear similar charges so that as soon as they settle towards each other their electrical charges cause them to be repelled, and they are kept in a state of constant agitation. If we insert positive and negative poles in a colloid the charged particles are attracted to one of them where they give up their charge and either adhere to the electrode or settle out under the influence of gravity. The commercial possibilities of this type of precipitation are rapidly becoming appreciated, and the process is already in use for refining clay and for coating articles with rubber.

If now we consider the combinations of atoms which form different substances, we find that these can be divided roughly into two classes. In one class the atoms are so disposed towards each other that they are continually exchanging electrons, as the negative particles of electricity are called; we can imagine electrons jumping from one atom to another, in every direction like a swarm of gnats on a summer evening. In the other class the electrons remain stolidly rotating in their own orbits and no interchange of electrons takes place between the atoms.

The materials included in the first class are what we call conductors of electricity and are chiefly metals, whilst those in the second class are called insulators. If we apply a difference of potential to a piece of metal the swarm of electrons is attracted by the positive pole and the individual electrons go jumping from atom to atom, all in the same direction. This stream of electrons is what we call an electric current and, contrary to our old established ideas, it flows from the negative to the positive pole. If we apply a difference of potential to an insulator there are no free electrons to be attracted by our positive pole so there is no electric current.

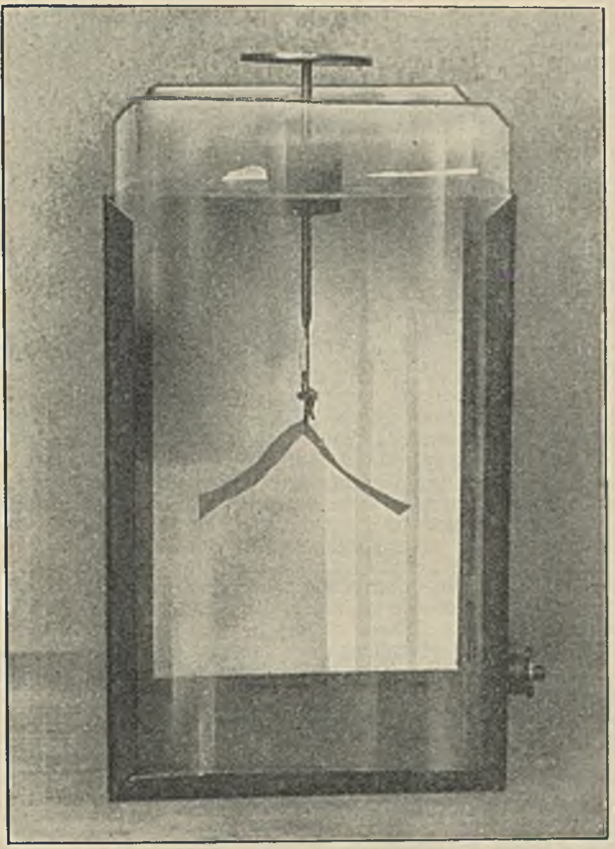


Fig. 1.—An Electroscope indicating that similar charges repel each other.

It is a well known fact that the best conductors of heat are also the best conductors of electricity and we are led to infer from this that the two phenomena have something in common. When a substance is heated its atoms are set into a state of vibration and the higher the temperature becomes the oftener do the atoms collide with each other. If we try to send a current through a substance whose atoms are in a state of violent commotion the passage of the electrons will be greatly impeded or, to use a well known phrase, the resistance of the material will have increased due to its rise in temperature. If the substance is heated to a sufficiently high degree the internal bombardments will become so great that electrons will be flung away from the metal. This is what happens when we heat the filaments of our wireless valves. A reversal of this procedure occurs when we try to force a great number of electrons through a very thin piece of wire. The violent shocks given to the atoms cause them to vibrate and produce heat whilst the sudden stoppages of the electrons in mid flight produce, as we shall see later, waves of heat in the ether. If a conductor can be made sufficiently cold the atoms become so calm and quiescent that if we start a current flowing in the conductor and then remove the source of E.M.F. the current will continue flowing for several hours.

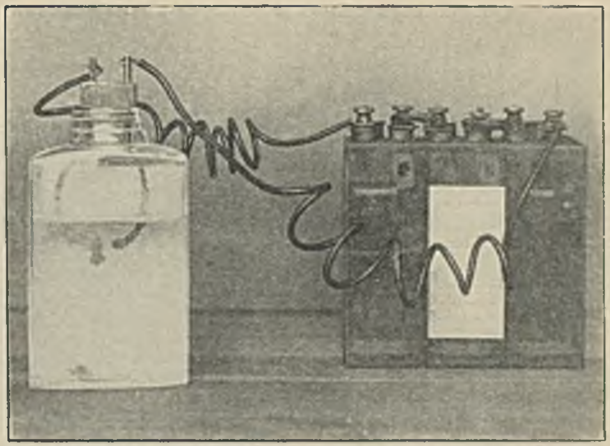


Fig. 2.—The Electrolysis of Lead Acetate.

Now that we can form some conception of what an electric current really is and can visualize it as a procession of electrons along a conductor, let us see what effects are produced by these currents. In the first place we find that each electron is surrounded by a field of magnetic force which we call its magnetic field, and when a current flows along a conductor these fields add up and form a field around the conductor itself. If the conductor is bent in the form of a helix the magnetic fields around each turn fall into line and the helix becomes an electro magnet. If we have two parallel currents flowing in the same direction the magnetic fields tend to embrace and the two conductors are attracted to each other. If the streams are in opposite directions the conductors repel each other.

Some metals have their atoms so arranged that the magnetic fields set up round their little whirling electrons can be made to add up and form one common field. When a metal is in this condition it is called a permanent magnet.

Faraday discovered that a current flowing in one conductor could induce a current in a parallel conductor placed near it, and it is this phenomenon which is the basic principle of all our transformers and electric generators. What happens is that the field produced

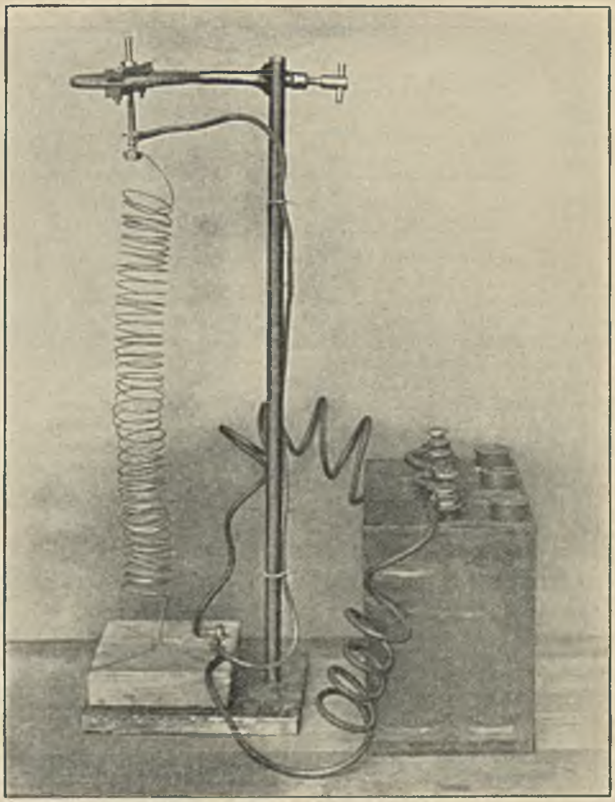


Fig. 3.—Demonstrating the Magnetic Field of a Spiral Conductor. "The Jumping Spiral."

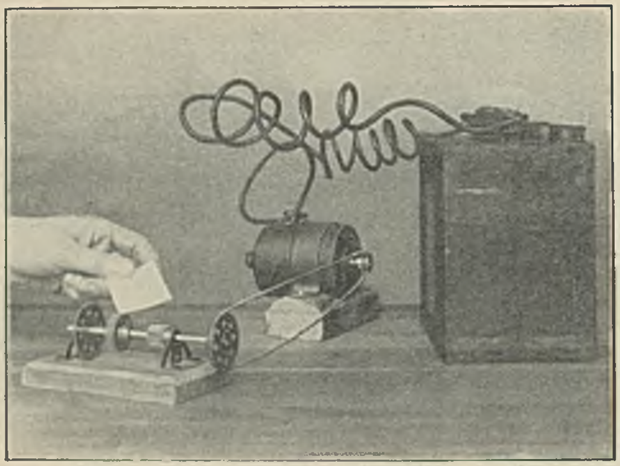
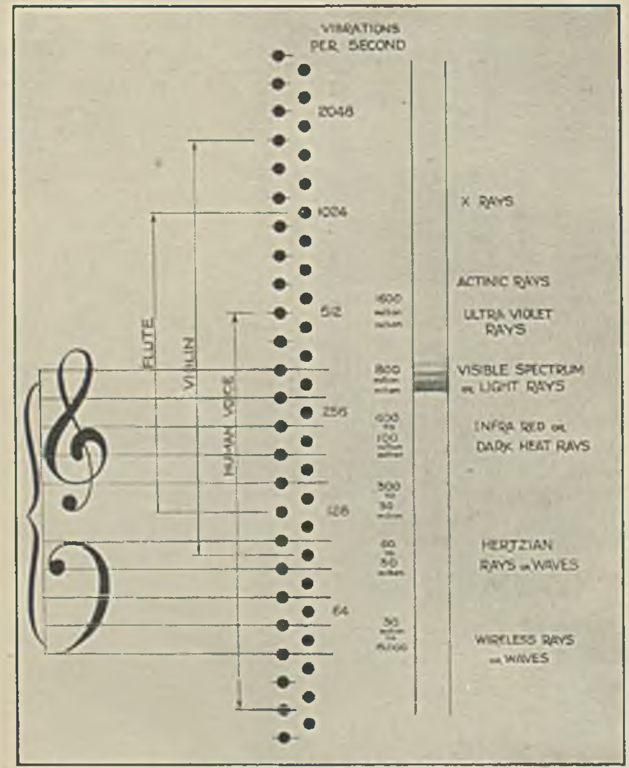


Fig. 4.—Demonstrating the Frequency of a Musical Note.

by the current in one conductor influences and drags along the free electrons in the other conductor, producing in this manner an induced current. We can imagine the electrons in the second conductor becoming entangled in the magnetic field which carries them along.

There is another property connected with our moving electrons which is of universal interest for it is on this property that we depend for our wireless, our X-rays, and even for the light by which we see. The property referred to is that of being able to produce what are known as ether waves and it will probably be of interest to consider this action in greater detail.



SOUND WAVES ETHER WAVES.

Fig. 5.—Composite Chart of Musical Scale and Ether Vibrations.

When an electron moves through space it carries with it a region of electric strain which we call its magnetic field. If the career of the electron is suddenly stopped short this field of force does not stop short with it but is carried forward as if by its own momentum; and it is this overshooting of the electron by its magnetic field which produces what is known as a wave in the ether. We all know what is meant by a wave in water, and most of us know what is meant by a sound wave, which is simply a wave set up in the air. A thorough knowledge of these phenomena is of considerable assistance when considering the nature of ether waves, for there are many fundamental principles which are common to all classes of wave motion. If we realize then that we can produce waves in the ether by causing more or less rapid vibrations of the electrons, and that by controlling these vibrations we can cause different numbers of ether waves to be sent out per second, it will probably be helpful to consider the somewhat similar case of vibrations which can be set up in the atmosphere, and to examine the effects which are produced by varying the frequency of these vibrations.

A musical note is produced when a definite number of blows or impulses is given to the air per second. This fact is not fully appreciated until we study the motion of the prongs of a tuning fork or hold a card lightly on the periphery of a revolving toothed wheel. If we give 256 vibrations or minute impulses to the air each second we produce a musical note which we call middle C. If we cause the source of our sound to make 512 vibrations per second then the sound becomes an octave higher and just as the frequency of the sound wave is raised or lowered, so the pitch of the note produced is altered accordingly We see then that the whole of the musical scale can be traversed by a source of sound which can be made to vibrate at different frequencies. The only fundamental difference between one note and another is the frequency of the impulses that produce them.

Just as we have a range of vibrations of the atmosphere divided into octaves which we call the musical scale, so with our ether vibrations we have an extensive range of frequencies which is also split up into octaves. Near the upper or high frequency end of the range, and comparable with those musical notes which are too high for human ears to detect, we have the band of vibrations which produces X rays. These rays as we all know, pass easily through most substances and have the power of affecting photographic plates. Coming down to the lower frequencies we pass through the region of ultra-violet rays until we reach what is known as the visible spectrum. Here we pass through the various colours which make up the white light of the sun. Following the decreasing frequencies we come to the violet, indigo, blue, green, yellow, orange and the red rays. If a beam of ordinary white light is refracted or bent through a glass prism the amount by which each colour is bent is porportional to its frequency so that the emergent ray consists of a comparatively broad band made up of different coloured beams, which we call a spectrum. Travelling further down the scale of frequencies we come to the infra-red or dark heat rays. These are the rays given off from a body when we say that it is black hot. As we explore still further we come to the short wireless waves which were first discovered by Hertz, whilst a little farther below we have the low frequency long wave length wireless waves which are used for wireless transmission.

If we take a comprehensive view of the vast range of ether vibrations we see that the once mysterious X rays, the rays of light, rays of heat, and the rays propagated by a wireless transmitting aerial bear the same relation to each other as do different notes in the musical scale. Fundamentally in each case they are all vibrations or waves sent out in a common medium, the only difference in their effects being due to the different number of vibrations per second set up at their source.

Let us consider now the ground that we have covered. We have seen that all matter is composed of particles of electricity and that practically all the electrical actions with which we are familiar are due to movements of the negative particles of electricity or the electrons as they are called. It is due to their steady movement that we have magnetic fields, permanent magnets and electric currents whilst when they are violently accelerated they send out ether waves and produce the vast range of different effects that we have recently considered.

No attempt has been made to deal with this subject in a scientific manner, and the paper simply bristles with technical inaccuracies but, in the endeavour to convey in simple language an idea of the general trend of electrical science, what might be called pedantic accuracy has had to be forsaken in order that the subject could be treated with the greatest possible simplicity. If now, we can form a broad conception of the various actions which have been discussed, we should be able to realise in an exceedingly modest way the very important place that electricity holds in the great scheme of nature.

Note.—The subject has been considered throughout on the general lines of the Rutherford-Bohr theory of the atom and for the sake of simplicity the electron has been represented as a solid particle instead of as a twist in the ether as it is conceived by some scientists.

Discussion.

Mr. L. BARNEY, the Chairman, said they had had a very interesting address from which they could gather Mr. Cooper was very familiar with his subject. Most of the members present would doubtless feel that they knew more than they did when they came to the meeting. He invited a member to propose a vote of thanks to the author for the trouble he had taken in preparing the lecture and also for showing them such interesting experiments.

Mr. W. EDGAR said he had listened with great interest and he thought that Mr. Cooper was to be complimented on his courage in launching out on such a wide and difficult subject. Speaking for himself, Mr. Edgar said he had never tackled electrons and their brothers and sisters since early college days and he confessed to a slight tinge of disappointment in that he had quite expected the author to tell them exactly what electricity is. He noticed that Mr. Cooper had mentioned some place in England where they used electrons for abstracting carbon out of chimneys. He wanted to know if the same principle could be applied for abstracting dust. That was what they were well acquainted with around Tilmanstone, and it seemed to be a source of worry to the Adams and Eves in this Garden of Eden. He also wanted to know whether the principle of the precipitation by electrons could be applied to the colliery chimney where they had so much trouble in the form of stone dust and whether it would be successful in a job of that kind.

Mr. COOPER replied that he did not see why stone dust should not be precipitated in the same way as he had mentioned, and the only reason why it was not done more extensively to-day was because of the capital expenditure. The recovery of copper dust was commercially a sound job; but recovering smoke particles from boiler gases was more a general benefit to the community at large than to the colliery owner.

Mr. EDGAR asked whether the same principle could be applied to the cleaning of water and Mr. Cooper said that he saw no reason why it should not be effective in that case also.

THE CHAIRMAN said that in regard to that question he would like to say something. Some years ago he was the electrical engineer to a large oil refinery in Mexico; and he wanted to refer more particularly to the cleansing of oil, petrol, and paraffin. They used a large quantity of sulphuric acid which was put into a container called an agitator—like a large boiler lined with lead. The oil to be cleaned was put into it and "stewed" for about half an hour and mixed by compressed air, then the oil and acid mixture was taken out and separated. After the process there was a lot of acid over which was wasted; they used something like 20 tons a day and the greater part of that was absolutely wasted. One day the boss of the acid plant enquired of Mr. Barney as to whether there was any way of cleaning the waste acid stuff and using it again. They evolved a scheme and tried it out in a small way. They put some of the dirty oily remainder into an old battery box with several plates in it and then put a low voltage—about 80 volts—across the plates for about ten hours. They found, as Mr. Cooper had demonstrated, that the dirt accumulated on these plates an left the acid practially clean. A large refinery near them went one ahead and put up a large plant on these lines and in this way they saved many thousand pounds in a year in cleaning acid which would otherwise have been waste discharged into the river. He supposed that water could be similarly cleaned.

Mr. J. G. RUSSELL said Mr. Cooper mentioned the precipitation of smoke in some place in England. Could he say where it was?

Mr. COOPER said he could not from memory, but he would be able to obtain the information for him. He understood that the voltage used was in the region of 40,000 volts to 100,000 volts D.C.

In reply to the Chairman who asked a question regarding the collecting of sulphur fumes. Mr. Cooper said that no doubt under correct electrical treatment it could be done, but there again they were faced with the question of capital expenditure which would necessarily be very heavy.

Mr. RUSSELL said that Mr. Cooper had told them about electrons running in their own orbits. Could Mr. Cooper say what would happen if two of these atomic bodies came off their tracks and collided.

Mr. COOPER said that normally they would not actually collide because when they came together their magnetic fields would meet and repel each other, and the electrons would be deflected.

YORKSHIRE BRANCH.

Modern Lead Storage Batteries and Their Application in Mining Work.

C. P. LOCKTON.

(*Paper read November* 16*th*, 1929.)

Modern electrical engineering dates from the discovery of the dynamo about half way through the last century. The reversible storage battery was invented about the same time and has developed concurrently with the advances in electrical machinery. It has played an increasingly important part in all branches of electrical engineering, and in mining work particularly its applications to-day are so widespread that an understanding of storage battery design, operation, and maintenance, is a matter of very considerable importance to mining electrical engineers.

Batteries of the primary or non-reversible type were well-known before the invention of the dynamo. After this the call for primary batteries to some extent lapsed, but an urgent need arose for a reversible cell which could be recharged electrically after being discharged. To be successful such a cell must, among other things, be reasonably cheap to manufacture, must work at a reasonable efficiency, retain its charge well when not in use, and show a reasonable durability expressed in cycles of charge and discharge. The problem was solved in 1859 by Planté, who produced a battery consisting of two lead sheets immersed in a weak solution of sulphuric acid. By charging such a cell in the forward and reverse directions over a long period, the electrodes became coated with a thin layer of active material, which in the finished cell consisted of lead peroxide (PbO_2)

on the positive and spongy or porous lead on the negative. Such a cell works on identically the same principles as the modern lead storage battery. On discharge, the action is that combination takes place between the active materials of the electrodes, forming the compound known as lead sulphate. Acid is absorbed from the plates in this action, so that the electrolyte solution becomes weaker. On charge, the reverse action takes place, and acid is driven out of the plates; the solution, therefore, recovers its original strength and the plates return to their previous condition. A modern cell will last out a large number of cycles of charge and discharge, from a hundred or so to several thousand, depending on its type, before the plates become worn out.

The subsequent development of the lead battery has been in the direction of increased durability, reliability, and robustness. Electrodes of the Planté type, with a formed surface, are still used for stationary batteries, but the period of formation required is now only a few days instead of several months. For other types, plates of the pasted, or Faure type, are now used. These consist of grids of lead-antimony alloy, so designed as to hold in the active materials, which are applied in the form of a lead-oxide paste and converted to lead peroxide and spongy lead, for positive and negative plates respectively, by charging. The chief advantage of this type of plate is the increased capacity obtainable for a given weight of material

Modern portable cells are assembled in a container of some acid-proof material such as ebonite, celluloid, or glass, provided with a sealed lid of similar material through which project the cell terminals. The electrodes consist each of several plates joined together by means of a group bar, the positive and negative plates being interleaved. The object of this is to minimise the internal ohmic resistance of the cell and thus prevent unnecessary loss of voltage on discharge. One more negative than positive plate is usually employed, as it is particularly important to work each positive plate on both sides. The plates may either be suspended from the lid by means of the terminals, or supported on ribs on the bottom of the container. In either case, space is left at the bottom of the cell for the sediment or waste which is gradually thrown down from the plates during working. In order to prevent positive and negative plates from touching and thus causing an internal short circuit, porous insulating separators are placed between them. These usually consist of thin wood sheets, specially treated during manufacture to remove all resins and other deleterious constituents.

The lead cell at the commencement of discharge gives about 2.0 volts, which gradually falls as the discharge proceeds. For practical purposes it is usually regarded as discharged when a voltage of about 1.8 is reached, but the final figure varies somewhat with the rate of discharge. To obtain a higher voltage it is clearly necessary to connect a number of similar cells in series, thus constituting a "battery." The capacity of a battery, which is stated as so many ampere-hours, depends only on the size of the individual cells. On the commencement of charge, the voltage gradually rises from 2.1 to 2.4 volts. As the plates approach a fully charged state, the voltage rises quite abruptly to about 2.6 to 2.7 volts per cell and, at the same time, "gassing" commences. This is because the plates are now no longer capable of absorbing all the charging current, and the surplus current commences to split up the water portion of the electrolyte into its constituent oxygen and hydrogen. Under normal working conditions, the ratio of discharge to charge, expressed in ampere-hours, is about 90%. Expressed in watt-hours the ratio is about 75%, since the fact of the voltage being higher on charge than on discharge has then to be taken into consideration.

The fundamental rules of battery operation are simple and the basic reasons for them may be quite easily explained. Cells should not be discharged right down to complete exhaustion, nor should they be allowed to stand for long periods in a discharged state. Under such conditions the lead sulphate tends to harden and become unresponsive to charging, with resultant loss of capacity. The strength of the acid, which can be read by a hydrometer, is a useful guide to the state of charge of a battery, and such readings can therefore be used to indicate when a recharge is required. In this respect they have the advantage over volt-meter readings, which are affected by the value of the current flowing at the time and may, therefore, be misleading. Voltage readings are entirely valueless if taken when no current at all is flowing.

Recharges should be kept on long enough to ensure that all acid is driven out of the plates, otherwise some of the capacity may in time be permanently lost. This will be indicated by the hydrometer readings having reached a maximum value and showing no further rise. Charging beyond this point on the other hand will only result in further gassing and unnecessary wear of the plates. Similar results will occur if the charging is given at too high a rate towards the end, but when time is limited there is no objection to commencing the charge at a high rate as no gassing occurs during the initial stages. High temperatures, i.e., above say, 110°F., should be avoided as they may shorten the life of the plates; this is another reason for keeping the charge down to a low rate during the gassing stages.

In the course of service, loss of water from the electrolyte gradually takes place, due to evaporation and the splitting up of the water into hydrogen and oxygen when the cells are gassing on charge. No acid, however, is lost (except very gradually by spraying) so that only water must be added to maintain the level of electrolyte, which should always be high enough to cover the plates completely. The water added should be of a high degree of purity, since very small traces of foreign substances may affect the working of a cell. It is safest to use only distilled water, but rain water is permissible in most localities if carefully collected.

TRACTION BATTERIES FOR ELECTRIC MINE LOCOMOTIVES.

The use of electric traction in mine work has made considerable headway of recent years, though perhaps not to the same extent in this country as in America. The first question to be considered is that of the haulage of materials on the surface, where it is tending to replace the use of steam and oil engine locomotives. Then there is the important question of underground traction in the mine workings, which involves the haulage of materials and also the carrying of men to and from their work, and in which the electric locomotive has to compete also with traction by means of pit-ponies and even by man-power. In these applications electric traction scores by reason of economy, convenience, and efficiency. As regards the question of economy, which means, in the end, the reduction of production costs, there is no need to dwell on the fundamental importance of this in the present state of the mining industry. In general it may be said that two electric locomotives will deal with the same amount of work as three steam locomotives—will deal with it more speedily and with less crew, and with no loss of time in fuelling, taking in water, or getting up steam.

Electric mine locomotives may either be of the trolley type, taking their power from an overhead line, or they may take their supply from a battery actually carried on the locomotive. The particular advantages of the battery locomotive are chiefly felt where short hauls in temporary workings are required, or in the case of infrequent long hauls where trolley lines are not warranted. Many cases arise in mines with low-roofed wet workings where trolley lines are not practicable. A battery locomotive system is cheaper to instal than the other, owing to the cost of the trolley line circuit. The former has also the advantage of reduced danger from shock, and it avoids the necessity of wiring and bonding the track, which arises unless two trolley lines are used. In fiery mines a battery locomotive can be completely enclosed and made explosion-proof, whereas under such conditions trolley locomotives would be out of the question, owing to risk of sparking at the collector.

It is interesting to note that when changing over to electric traction for underground work, it is found to be a paying proposition to go to some expense in track preparation in order to achieve the most economical and trouble-free running. The provision of a well-laid track, the smoothing out of sharp bends, and the levelling up of the more abrupt gradients, are all points which well repay preliminary attention. Any reasonable expense on these items has been found in practice to be amply covered by the subsequent saving in operating costs.

To give an idea of the widespread use of the battery mine locomotive to-day, it may be mentioned that in America alone there are estimated to be well over 4000 of them in active operation. Most of these are employed on collection work, not only in coal mines, but in lead mines, ironstone mines, and many others. One interesting development in colliery work is the use of a self-propelling locomotive which is run up to the coal face, where the battery is used as the source of power for electric coal cutting machines.

A brief description of two representative cases where Storage Battery Locomotives are in regular service may be of interest. One of these is at a colliery in Scotland, where a locomotive of this type is actually engaged in bringing out between 350 and 400 tons of coal in a shift of 7 hours, operating on a road about ¾ mile in length. The overall cost of operating the locomotive, including for full interest and depreciation charges on batteries, locomotive, and charging plant, and inclusive of all running charges such as power, drivers' wages, oil, waste, and stores, is about 4s. per hour, or £1 8s. per shift, so that the total cost of hauling the coal to the pit bottom is less than one penny per ton. The coal can be handled in sets of anything up to forty tubs, and generally the sets consist of thirty-two tubs. The capacity of the tubs is between ten and eleven cwts., the tare weight being about four and a half cwts., so that the amount of coal handled per trip is about sixteen tons. The locomotive has a total weight, including battery, of about five tons. It is equipped with two 6 H.P. 80 volt, series wound motors, each driving one axle on the locomotive. The whole of the electrical equipment is completely flameproof.

Owing to the heavy duty required, it was found most economical to provide two batteries, which are changed over half way through the shift, and recharged while off the locomotive. To enable this to be done quickly, special removable battery boxes are provided. Each battery consists of forty-eight cells, having a capacity of 290 ampere-hours, which is equivalent to an output on one discharge of five and a quarter kilowatts for five hours. The battery voltage throughout a discharge averages about ninety volts, which gives the locomotive a maximum speed of about five miles per hour. It may also be noted that, working from this battery, the motors will develop a tractive effort of 1,100 lbs. at the wheels continuously for one hour, and for short periods of up to about 2,200 lbs. which is the limit of rail adhesion. They are designed to give these outputs without undue heating.

Another specific case of interest is that of a battery locomotive used at a Northumberland colliery for conveying miners to and from the coal face. This locomotive with its battery weighs seven and a half tons and is fitted with two fifteen horse-power motors. The total weight of a complete train, including the men, but excluding the locomotive, is about 28 tons. The train will accomodate 300 men in 25 coaches, each holding 12 men. The average speed of the train is about eight miles an hour. Approximately 1,000 men and boys are taken in and brought out each day. Compared with the previous necessity for these men to make this journey on foot, a saving of about 40 minutes per man per day is effected, which is equivalent to 660 man-hours per day. The cost of operating this locomotive, including all factors such as depreciation, power, materials, and wages, is, in practice, about £3 per day, which per man per mile works out at only 0.06 pence. Two batteries are provided, so that one may be charged while the other is in use, changing over being effected every twelve hours. Each battery consists of 48 cells of 387 ampere-hours capacity.

Considering now the type of battery to be used for mine locomotive propulsion, it is clear that robustness, particularly as regards immunity from damage by vibration, must be a predominant feature of the design. The conditions of service are very similar to those of electric truck and road vehicle propulsion, and the types of cells to consider are identical with those used for these other services.

The number of cells in a locomotive battery depends to some extent on the size of the locomotive. Clearly in a large locomotive a comparatively high working voltage, and therefore a large number of cells is desirable; otherwise individual cells of unwieldy size would be necessary. The driving motors can be designed without much difficulty to suit any battery voltage and in actual practice the exact number of cells is usually decided by the voltage of the charging supply. Thus, batteries of 40 to 44 cells are common, as they can be charged conveniently and efficiently from 110 volts; likewise batteries of 80 to 88 cells are suitable for charging from 220 volt supplies.

The individual cells are usually assembled in wooden trays, the number of cells per tray being so arranged that each tray weighs about 500-600 lbs. if intended for crane handling, and about 200 lbs. if for man handling. The cell containers are of ebonite, with sealed lids of the same material, into which are screwed specially designed vent plugs in order to prevent spillage of acid. For this same reason, very careful sealing arrangements are necessary at the points where the terminal pillars pass through the lid. This may be effected by means of a collar which supports the lid, a soft rubber gasket being placed between the two. The post is threaded where it passes through the lid, and the sealing nut clamps the lid tightly, compressing the soft rubber gasket underneath and thereby giving a very effective seal.

The type of inter-cell connector frequently employed consists of thin strips of copper, electroplated with lead to prevent corrosion, and with their ends cast into lead alloy terminals. These terminals are in the form of rings which slip over the pillars of the cells to be connected, and are then burned up to the pillar with a hydrogen flame, or by an electric arc welder. This built up connector of copper and lead is not only flexible and of high conductivity, but is a strong and reliable job, and is not liable to damage by spilled acid.

In the internal construction of a traction cell the design of the positive plate is a factor of great importance. It is also essential to provide proper internal packing to ensure rigidity of the element. The negative plate presents no particular difficulty, as its active material is soft and spongy, and is not liable to be affected or shaken out by vibration. It is usual to design the negative plates so that they will have approximately the same life as the positives, and thus avoid the necessity for partial renewals to the cells. The ordinary flat pasted type of positive plate has not a very good life under traction conditions, as the vibration tends to loosen the lead peroxide which forms the active material. Some form of protective armouring is therefore provided in order to increase the durability of the positive plates.

One method of doing this is to make the armouring an integral part of the positive plate, as is done in the case of the Exide-Ironclad battery. This type of positive plate is built up of a number of specially shaped antimonial-lead rods held in a vertical plane by top and bottom castings of lead. These rods are surrounded by sheaths, or tubes, of a special class of ebonite, in which they stand concentrically, the space between the rod and the tube being filled with the active material. In this plate the peroxide of lead used for the active material is so applied that it entirely fills the space round the lead rod and inside the ebonite tube, and when fully "formed" it becomes a close-fitting tube making perfect contact with the supporting rod. The ebonite tubes are slitted horizontally to allow the electrolyte to gain access to the active material; and, further, they are of an appreciably elastic nature, and so allow for expansion or contraction of the active material during use. The slitting of the tubes is an extraordinarily fine piece of work, the slits being such that no active material can fall out from the tube, and yet the resistance to the electrolyte is reduced to a minimum.

The Exide-Ironclad negative plate, for the reason explained above, is similar in design to an ordinary flat negative. It consists of a grid of hard antimonial-lead, supporting and containing strips of active material. This material is applied originally to the grid in the form of a paste, and owing to the special lattice design of the grid it is held firmly in close contact with the grid, in the form of vertical strips which extend right from top to bottom of the plate.

It will be gathered from the foregoing description of the plates that there is little risk of the positive and negative grids coming into electrical contact through buckling or distortion, as the positive grid is protected by the ebonite tubes. A further precaution is taken, however, by the use of thin diaphragms of prepared and treated wood, one on each side of the positive plate. The ebonite tubes have a vertical ridge on each side, and these ridges bear against the wood diaphragms and hold these latter up against the negative plates. The whole element, consisting of positive and negative plates and wood separators, is therefore strongly built up, and would be actually solid but for the space left for electrolyte by the circular section of the rods in the positive plates

An alternative method of protecting the positive plate is adopted in the "Kathanode" type of traction battery. Here a flat type of positive is used, wrapped round with a sheet of finely spun glass wool, which performs the function of holding in the active material but at the same time of allowing free passage to liquid and gas. In addition, two wood separators, one plain and one grooved, are fitted between each pair of plates, this combination permitting free circulation of the electrolyte. Flat negative plates are used and the general assembly and arrangement of the cells do not differ fundamentally from the type previously described.

As regards the life obtained in service from modern lead batteries on traction work, it may be mentioned that most makers issue a guarantee of three years on them, provided that certain simple conditions are complied with. Where good conditions of charging and general maintenance are in force, a life considerably exceeding this is frequently obtained in practice.

The procedure and equipment for charging are important items in a battery locomotive scheme, and satisfactory charging is by far the most important factor in the battery maintenance. In many cases the battery charging is done *in situ* on the vehicle, but clearly this is only possible where the locomotive is out of commission at least twelve hours in the twenty-four. For underground work, however, this is frequently not the case, and apart from this, the design of an underground locomotive with enclosed battery compartments, does not lend itself to charging the battery on the vehicle itself. In such cases the battery boxes on the locomotive are made easily detachable, as for instance by the method of mounting them on rollers so that they may be easily slid off in a sideways direction.

One factor to be considered when planning out the charging routine is the amount of work which the battery is called upon to do. In order to obtain the maximum life from the battery the number of charges given should be limited to the necessity imposed by the service, i.e., if the battery is capable of dealing with two days' work without a recharge, it is better to give a long charge every other day than a short charge every day. When the cells are in a condition approaching full discharge, the recharge should be started as soon as possible, as any delay increases the time required for completing the charge, and also tends to have a harmful effect on the plates.

It has already been mentioned that the most reliable method of ascertaining the state of charge or discharge of any battery, and of determining when a recharge has been quite fully completed, is by hydrometer readings of the specific gravity of the electrolyte. This latter point is so important that it is always recommended that once per week the ordinary recharge should be specially prolonged, at a lower rate than the ordinary charge rate, until the specific gravity of a representative or pilot cell has remained constant for at least four successive hourly readings. Once a month, in addition, it is advisable to give a special equalising charge on the foregoing lines, but taking readings of every individual cell, so as to ensure that all of them are brought fully up and are in step with the pilot cell. It is a further safeguard on these occasions to take individual cell voltage readings as well, so as to check that these also are brought up to a maximum stationary value before the current is shut off.

For the ordinary recharge it is quite permissible to adopt a simpler method of regulation which does not require the taking of hydrometer readings. This is usually done by means of an ampere-hour meter mounted on the vehicle, which indicates directly the number of ampere-hours taken out of the battery since the previous recharge. By comparing its reading with the known ampere-hour capacity of the battery, the state of discharge of the cells can be approximately gauged, and an indication is given of when the cells require recharging. On charge, the pointer of the instrument is usually arranged to move back towards the zero mark. As the efficiency of any battery is about 90%, the instrument is set to read about 10-12% slow in the charge direction, thus by the time the pointer has returned to its zero mark, the cells will have received this amount in excess of their previous discharge and the charge may then be cut off. It will be seen that for equalising charges, however, the charge is continued beyond this point, and during this latter period the indications of the meter are ignored, reliance being then placed upon the hydrometer and voltage readings only.

There are three possible systems by which ordinary recharges may be given to a vehicle battery. The first, which is known as the Constant Current method, necessitates the manual adjustment of the current throughout the charge. The charge is commenced at a constant rate which may be anything between half and three times the nominal charging rate of the battery. When the cell voltages reach 2.4 volts, which is the point at which gassing commences, the rate must be reduced to a lower, or "finishing" rate, at which it is maintained until the charge is completed.

The second system is known as the Modified Constant Potential system, and has the advantage that the rate is adjusted automatically, so that less supervision is required. The battery is connected to a constant voltage dynamo or main equivalent to about 2.6 volts per cell; thus for example, a 100 cell battery would require a 260 volt supply. In series with the battery is connected a small fixed resistance, the value of which can be calculated from a simple formula. On first switching on, a comparatively heavy charging current flows, limited however, to a safe value owing to the presence of the resistance. As the charge proceeds, the battery voltage rises and offers greater opposition to the voltage of supply; hence the charging rate falls off automatically and at the end of the charge is reduced to a safe figure which does not cause excessive gassing. It is then simple to arrange for the ampere-hour meter to make a contact when the hand reaches the zero mark, so that a circuit breaker in the charge circuit is tripped and the charge is automatically cut off.

The third system is the Straight Constant Potential system, in which the battery is connected direct to a constant voltage supply, equivalent to 2.3 volts per cell, without any intervening resistance. As before, this results in a tapering charge rate, but when this has fallen to the nominal finishing rate it is desirable to maintain it at this figure by manual adjustment for the rest of the charge. This system is not in very frequent use and is not altogether recommended. It enables the charge to be completed in a minimum possible time (about 5-6 hours) but it requires considerable manual adjustment and supervision, particularly as there is more risk of the cells being overheated. It requires very heavy cables and fuses, etc., and is much less stable than the Modified Constant Potential method. With the other two systems, charges can usually be completed in 8 hours. In all systems an occasional watch must be kept to see that the temperature of the cells does not exceed 110°F. If it does, the charging rate must be temporarily reduced.

The size of battery specified for a given locomotive will naturally depend largely on the work it will have to do; not only on the loads to be hauled, but on the nature of the track, particularly as regards the gradients and sharpness of curves. It is possible to estimate the capacity by calculation very approximately from the data of the track and working routine, but in actual practice the size of battery for a new job is more usually fixed from past experience of similar installations. The maximum loads, as well as the average loads, have to be taken into consideration, and it must always be borne in mind that the available capacity of a battery is less at high rates than at low rates of discharge.

It may be noted here that locomotive operators can reduce the drain on the battery very considerably by intelligent driving. For instance, when starting up against a gradient, the motors should not be driving against the brakes for more than a second or so. When stopping, the current should be cut off in good time, so that the locomotive may come to rest of its own accord, without wasting energy in the brakes. Again, in certain positions of the controller, no energy is absorbed in resistances; these positions only should be used for normal running, and in going up hills the one which gives the slowest speed will be the most economical. If the ampere-hour meter shows that more energy than before is being used on a normal run, without alteration in the conditions, the cause of this drag should be ascertained and removed without delay.

MINERS' HANDLAMP BATTERIES.

The use of electric handlamps in mines has now, to a large extent, superseded that of the oil burning type, on account of the steady illumination and simplicity which they afford. In fiery mines they ensure perfect safety since no flame or incandescence is exposed to the outside atmosphere.

Each handlamp is made up of three essential components; a single two-volt cell, a lamp bulb, and an external metal case to enable the handlamp to withstand the inevitable knocking about to which it is subjected. The lamp bulbs are usually designed to consume approximately one ampere, and the capacity of the battery is of the order of ten ampere-hours. This enables it to light the lamp, on one charge, for the duration of one working shift, with an adequate margin to cover the interval between the issuing of the lamp to the miner and the commencement of the shift, together with the corresponding period at the finish of the shift. Charging is carried out by transferring the cells to suitable racks, so arranged that they clip on to the charging terminals and no manual connecting up is necessary. The cells are charged in series-parallel so that a supply of suitable voltage can be utilised.

The containers of nearly all miners' handlamp cells are made of carefully seasoned celluloid. Apart from this one common factor, however, modern cells may be divided into two separate types, which differ from each other considerably in internal design. The simpler of these is the flat plate type, which usually has three positive and four negative plates with wood separators, and works in ordinary liquid acid, not unlike an ordinary wireless low tension cell. The lower portion of the cell is rectangular in order to accommodate the plates, while the upper portion is circular. The metal container of the handlamp is, of course, made of corresponding shape. To prevent corrosion by acid of the metal container the lid is provided with an acid trap to prevent undue spillage of acid when the cell is inverted or shaken. This device is necessary as no accumulator should be sealed hermetically; provision should always be made whereby any gases given off may escape freely without causing internal pressure.

The second type of miners' handlamp cell utilises one positive and one negative plate, both of cylindrical construction, the positive being inside the negative. No separator is used, the plates being kept apart by the fact of their resting in a slotted celluloid "cross" at the bottom of the cell. The cell container and the outer metal container of the handlamp are in this case both purely cylindrical. To achieve unspillability in this type jelly acid is used, no appreciable amount of free liquid being present. Jelly acid is prepared by mixing sulphuric acid and sodium silicate in suitable proportions and strengths. Its use is, generally speaking, not advantageous to the working of any type of cell apart from the question of unspillability. It so happens, however, that its disadvantages are at a minimum with the circular design of plate, and are further reduced under the particular conditions of operation of miners' handlamp cells; namely, frequent bumping which keeps the jelly in contact with the plates, and regular daily recharging.

Both types of cell give good results in practice, and under ordinary service conditions, a life of a year or even more may be expected from one set of plates. A great deal can be done to ensure good results and long life by attention to one or two points in the treatment of the cells. As regards the flat plate type, the treatment recommended does not differ greatly from that required for ordinary portable cells, except that under miners' handlamp conditions, where some loss of acid does normally occur, it is found advisable to use 1.100 gravity acid and not water for maintaining the level. Clearly, however, this can only be a compromise, and it is a precaution to check the specific gravity occasionally at the end of charge to see that this is coming up approximately to the correct figure. Under ordinary conditions it is advisable to remove the sediment from under the plates every four to six weeks in these cells. This involves thoroughly shaking the cells and pouring off the old acid, which should be promptly replaced with new, in order to minimise exposure of the plates to the air. To ensure the subsequent working specific gravity being correct, it is essential to change the acid while cells are in a fully charged condition, and to follow the makers' instructions regarding the strength of the new acid.

The first charge of new cells is an important factor in ensuring subsequent good service. The first charge should always be adequate in duration and rate, and in this respect again the makers' instructions are the best guide. In jelly acid cells the first charge is actually given in free acid; they are then discharged in the lamps for 8 hours, the free acid discarded, and freshly prepared jelly electrolyte is poured in. After standing for 12 hours to allow this to solidify, the cells are recharged and are then ready for service. As regards ordinary recharging in service, the usual rule is to charge at 1.2 amperes for as many hours as the lamp had previously been alight. Since the discharge rate is approximately 1.0 ampere, this allows an adequate excess of charge over discharge to compensate for the efficiency of the cell. As, however, there are bound to be individual variations as regards the consumption of lamp bulbs and in the charging rates, it is advisable to check occasionally that the charges are correct. The voltage of the cells should have reached a maximum and shown no rise for about an hour before the cells are taken off charge.

Evaporation takes place with jelly acid as with free acid, tending to cause hardening and cracking. This should be compensated for by adding a little further jelly electrolyte (freshly prepared) at intervals of ten to fourteen days. In order to remove sediment the cells should be dismantled every five months, while in a discharged condition, and the plates washed carefully in lukewarm water, not under pressure from a tap. The container should be washed out, and the cell reassembled and refilled promptly with fresh jelly electrolyte. It is very important that the plates should not be exposed to the air any longer than absolutely necessary.

These points of operation have been stressed in this paper because they embody the fruits of a long period of experience, and it is hoped that they will be of assistance to any engineers who may be in charge of electric handlamp departments in collieries and other mines.

BATTERIES FOR SIGNALLING, SWITCHGEAR OPERATION, AND EMERGENCY LIGHTING IN MINES.

While the two most important applications of storage batteries in mining work have now been discussed, there are a number of others which must not be overlooked and which show considerable promise of future development.

First among these is the use of batteries for mine signalling, where an unfailing supply is required at a comparatively low voltage. For cases where the discharges are frequent or continuous, it is obvious that frequent recharging will be necessary unless unduly large cells are used, and under such conditions, stationary type cells with Planté plates are most suitable. At a number of collieries 24 volt batteries are used, each containing 12 cells of this type, with a capacity of about 150 to 200 ampere-hours. Each installation has two batteries which are discharged alternately, so that one is available while the other is being charged. During the last few years stationary batteries up to 180 ampere-hours have been developed in a sealed-in design which can actually be supplied in a fully charged condition. No erection or long first charge is necessary, as in the case of ordinary open type stationary cells, but plates of similar type are used. Thus the positive plates are of pure lead castings with a surface of Planté formation, and the negative plates are of the box type, which are pasted and have the active material enclosed in a perforated framework.

For signalling and bell operation, where the discharge currents are only momentary, any battery will naturally require recharging at very infrequent intervals. Planté type plates will therefore not be suitable, and it is then usual to employ portable cells with very thick pasted plates known as "block" or "mass" type plates, and which have the property of holding their charge for long periods without risk of sulphation or loss of capacity.

Small portable batteries are also used for shot-firing purposes; a typical case being a 12 volt set of about 50 ampere-hours capacity. Such batteries are of generally similar design to those employed for motor car starting, but with rather thicker plates. It may be necessary, in order to protect them or from considerations of safety, to enclose them in explosion-proof steel containers of the usual type, fitted with flanged and machined joints.

Now that many collieries are being entirely electrified, in spite of the fact that alternating current is being usually employed, the storage battery has several important parts to play. One of these is in the work of switchgear operation, for which is required a source of direct current which must be of considerable overload capacity and not subject to failure in the event of an emergency shut-down of supply. In many cases of large and frequently operated switchgear, electrical closing by means of solenoids is employed, and this necessitates a comparatively large stationary battery, usually of about 60 cells. These may be either of the sealed in or open type, depending on their size, and will utilise Planté-formed positive and pasted box negative plates. Where such a battery is installed, it is commonly used also for supplying the switchboard lighting, so that this may not be affected by a failure of supply.

A battery of this type may be operated in the standard way by giving it periodical recharges, but there is the difficulty that switchgear operating service, except in times of emergency, does not give the cells sufficient regular work to keep the plates in really healthy condition. It has hence become the practice to adopt a trickle charge system of working in these cases. This means that a continual charging current, only a small fraction of an ampere, is passed through the cells, this being just sufficient to compensate for the gradual internal loss of charge which tends to take place in the cells while standing, and, in addition, to make up for the momentary discharges taken for the switches. By this means the battery is kept always in a fully charged and healthy condition in readiness for any emergency. The switch-board lighting may be also taken from the source of trickle-charge supply in parallel with the battery, or it may be taken from the alternating current mains with arrangements for switching it over to the battery in the event of emergency. The trickle charge current for the battery may be obtained from any convenient D.C. source through a series resistance, or from the main A.C. supply through a transformer and rectifier. After any heavy emergency discharge, the battery must be charged up again at normal rates from a generator or other supply before it is put back on trickle charge.

For small and infrequently operated switches in unattended substations, hand closing is resorted to and the battery is simply required for tripping, which takes only a comparatively small current. In these cases a small battery of the "Mass" type (already described) is used, kept in a fully charged condition by trickle charging from the A.C. supply, through a small rectifier of the Westinghouse "Metallic" type. The cells merely require attention every six months when they are topped up with water, hydrometer readings taken, and the trickle charge rate adjusted if necessary.

In all electrified mines, cases arise where it is essential that the lighting of certain places must not go out, even on failure of the main supply. The engine room may be a case in point, also certain special places in the mine itself where men have to be collected and where panic must be prevented. An emergency lighting system can be installed to deal with this problem, comprising a stationary battery which is wired up to special lighting points at selected key positions. On a failure of supply, an automatic switch puts the battery on to the emergency lights, and when the main supply is resumed, the emergency lights are automatically extinguished. The pioneer system of this kind is the "Keepalite," in which the automatic switches are mounted on a special enclosed panel, together with arrangements for trickle charging the battery from the mains. This keeps the battery fully charged and ready for emergency. There is also provision for giving the battery a special recharge after any emergency discharge. The batteries used with the "Keepalite" system are of the sealed-in stationary type and range in capacity from 30 to 180 ampere-hours, and from 25 to 100 volts. The smallest size would, in emergency, illuminate 13 30-watt lamps for one hour or 6 lamps for 3 hours; the largest size 300 lamps for one hour or 143 lamps for 3 hours. The "Keepalite" system is also in very wide use in hospitals, cinemas, large shops, etc., where an emergency lighting supply is absolutely essential.

Space does not permit mention of further application of batteries to mining work, but the Author hopes that enough has been said to indicate the many ways in which batteries are now being used and the important advantages which their adoption in many instances provides. He will, further, feel amply repaid if the details given in this paper regarding battery operation and maintenance should be found of interest and help to Engineers in charge of Battery Plant.

Discussion.

Mr. CROSSLEY asked why excessive frothing occurred in some of the batteries with celluloid casings.

Mr. LOCKTON.—Frothing of such a battery can only be caused by chemical action between the acid and the celluloid. To prevent this under ordinary conditions the celluloid is carefully selected and seasoned; it is also recommended as a precaution that the acid should be completely changed once a year. The most usual causes of frothing are the use of acid of too high gravity, or the overheating of the battery by charging at too high a rate while the cells are gassing.

Mr. MANN.—Mr. Lockton mentioned in his paper the use of the trolley system. This is prohibited by the Coal Mines Act and is therefore only applicable to the surface. Is a watt-hour meter attached to the battery locomotive or is it attached to the battery itself?

Mr. LOCKTON.—In cases where it is necessary to change batteries during the working period of the locomotive, it is usual to attach an ampere-hour meter to each battery box.

Mr. MANN.—Where batteries are used for signalling purposes underground, excessive current may flow when a short circuit takes place, and the usual method is to employ high resistance Leclanche cells.

Different manufacturers give a different specific gravity of the acid required for storage batteries. What is the reason for this?

When neglected, hard sulphate appears on the surface of the plates. Is there any method of clearing this?

Mr. Mann said he had also noticed that with miners' lamps batteries there were sometimes hard patches on some of the plates. Is that detrimental?

Mr. LOCKTON.—Regarding the question of signalling batteries, it would be possible to prevent an excessive current flowing on short circuit by using an accumulator with a permanent resistance connected in series.

The value recommended for the fully charged specific gravity of a cell is necessarily a compromise. Sufficient H_2SO_4 must be provided to take part in the chemical action of the cell. This can either be in the form of a small amount of strong solution or a larger amount of weaker solution. The latter conduces to the longest life of the plates, but in portable batteries, where space and weight are restricted, it is necessary to use a rather higher gravity than in stationary batteries. The fully charged gravity is also so fixed that the strength will not fall below 1.100 when fully discharged.

When endeavouring to cure a sulphated cell the separators should first be examined. If they are impregnated with white hydrate they should be renewed. The cell should then be filled in with water and given a prolonged charge at less than normal rate until all plates gas freely and the gravity has shown no further rise for 10/12 hours. The temporary electrolyte may then be poured out and replaced with fresh acid of normal fully charged gravity.

Regarding hard positive plates of miners' hand lamp cells, Mr. Lockton said such a trouble was quite new to him, and he would not like to make any statement on the matter without having first examined the plates in question.

Mr. FIELDER.—The question of specific gravity is very rarely attended to by those in charge of batteries. What is the strength of the acid in the jelly cell?

Mr. LOCKTON.—It is one of the disadvantages of using jelly acid that it is not possible to take specific gravity readings or estimate its strength. A routine regarding strengths for original mixing and subsequent topping-up has been evolved by the manufacturers as a result of experience, and users would be best advised to work generally in accordance with this.

Mr. MANN.—If there has been a cell charged in the wrong direction, is it possible to bring this back to its former condition?

Mr. LOCKTON.—That would entirely depend upon the extent to which the charge in the wrong direction has been carried. The effect of a reverse charge is first to drop the cell voltage to zero and then to build it up in the reverse direction. If the battery has been brought completely up in the reverse direction the polarity of the plates will have been changed, and this will have seriously strained them. They may give some further service, however, if they are subsequently worked with their reversed polarity. No attempt should be made to reverse them back to their original polarity. If, however, the charge in the wrong direction was only given for a short time, there is no reason why much damage should have been done if a thorough recharge in the correct direction is given promptly.

Mr. CROSSLEY asked questions with regard to the nickel-iron cells.

Mr. LOCKTON.—Comparing them with lead cells nickel-iron cells will probably give a rather longer life, but their first cost on the other hand will be higher. More cells are required for a given voltage, and there is a greater falling off in voltage towards the end of discharge. As nickel-iron cells have a higher internal resistance than lead cells, their voltage on overload is not so good.

Mr. MANN proposed, and Mr. Eddershaw seconded, a very hearty vote of thanks for the paper and for the useful information which the discussion had brought out.

MIDLAND BRANCH.

Cascade Motors and Alternators.

LOUIS J. HUNT.

(*Paper read 23rd February,* 1929.)

The machines described in this paper all embody the principle of Cascade Coupling, that is to say they are, when running at cascade speed, the equivalents of two machines with their rotor windings connected in series or cascade. As these machines have only a single core, there exists really only one magnetic field, but this field is the resultant of two components each of which would exist separately in the equivalent combination of two independent machines.

The Principle of Cascade Working.

An induction motor is a transformer with a rotating secondary. If the motor is of the two or three-phase type the currents induced in the secondary windings, the rotor, are carried by bars lying in a magnetic field and the interaction between the field and the currents causes the secondary to rotate. In a direct current machine the currents are supplied to the rotating part by conduction; in an induction motor, by induction. When the rotor is turning, its bars cut the magnetic field and back E.M.Fs. are generated which, as in the case of the D.C. machine, are proportional to the speed of rotation. At synchronous speed the counter E.M.F., due to rotation, is equal to the E.M.F. induced by transformer action and there is no current in the rotor windings. The speed of a motor for any load is one that will produce a counter E.M.F. which will permit a sufficient current to flow in the rotor to produce the required torque. An E.M.F. of the same value as that induced in the rotor is also induced, by the main field, in the stator windings and opposes the E.M.F. supplied from the mains.

To cause the rotor to run at a lower speed the counter E.M.F. must be increased or a part of the E.M.F. impressed upon the rotor by transformer action, must be absorbed. The latter condition can be met by inserting resistances in the rotor circuits as is done when a motor is started, or has its speed regulated, by resistances connected to its sliprings. The speed is then reduced only by sacrificing efficiency.

In the cascade system the additional counter E.M.F. is provided by connecting the rotor windings to an auxiliary induction or synchronous machine or, in the case of the machines described in this paper, by causing a single structure to perform the duties of the main and auxiliary machines.

In order to describe more clearly the actions that take place we will first consider the rotor of an 8-pole induction motor coupled, both mechanically and through its windings, to the rotor of a 4-pole induction motor. If the stator of the 8-pole machine be connected to a 50 cycle supply, its synchronous speed will be 750 r.p.m. with the sliprings short-circuitted. Now consider the

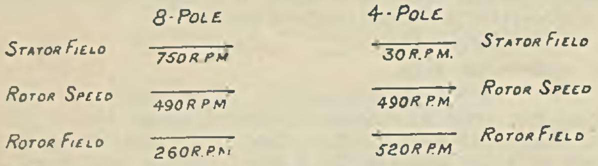


Fig. 1.

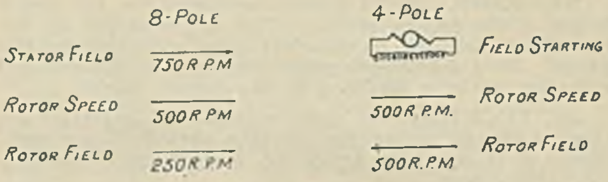


Fig. 2.

case when the sliprings are connected to those of a 4-pole machine, the speed of rotation being 500 r.p.m. The 8-pole machine is now running at two-thirds of its synchronous speed and the counter E.M.F. developed in its rotor is therefore only two-thirds of the E.M.F. applied to it by transformer action from the stator. Omitting the effects due to resistance losses, there must be provided by the rotor winding of the 4-pole machine the balance of the counter E.M.F. The power developed is proportional to the product of the rotor current and the counter E.M.F., therefore, two-thirds of the total power is developed by the 8-pole motor and one-third by the 4-pole machine. The comparison between speed reduction by resistance and by cascade control will now be clear. To reduce the speed by resistance to two-thirds of synchronous speed, one-third of the input to the rotor must be dissipated in external resistances whilst in the cascade case one-third of the input to the 8-pole rotor is supplied to the rotor of the 4-pole machine and does useful work.

The speed of the cascade set was assumed to be 500 r.p.m., which is the synchronous speed of the combination as the following considerations will show. The stator of the 8-pole machine is supplied with 50 cycle currents and its field rotates, say in a clockwise direction, at 750 r.p.m. As the speed of the rotor is 500 r.p.m.

$$\text{the slip is } \frac{750 - 500}{750} = \tfrac{1}{3}$$

The frequency of the rotor currents is, therefore,

$$50 \times \tfrac{1}{3} = 16\tfrac{2}{3} \text{ cycles.}$$

Currents of this frequency, fed into the auxiliary 4-pole rotor windings, provide a field rotating round the rotor at 500 r.p.m. in a counter-clockwise direction and, therefore, the 4-pole field is stationary in space and no E.M.Fs. are induced by it in the stator windings. The E.M.Fs. induced by transformer action are equal and opposite to the counter E.M.Fs. due to cutting the rotating field.

Now let us consider a practical case. Supposing under working conditions the slip is 2% or 10 r.p.m. The rotor turns at 490 r.p.m. and the currents in the 4-pole rotor creates a field which rotates round it at 520 r.p.m. Therefore, in space, this field rotates backwards at 30 r.p.m. and currents are induced in the 4-pole stator at a frequency of

$$\frac{30 \times 4}{120} = 1 \text{ cycle per second.}$$

Figure 1 illustrates this case.

The speed of the combination is that of a 12 (8 + 4) pole motor and, by connecting resistances to the stator of the second (4-pole) machine, the speed and starting torque are under complete control. As the two rotor windings are connected together, no sliprings are required. Combined in a single machine, as described later, this is the Single Speed Cascade Motor.

If sliprings are connected to the connections between the two rotor windings, and these are short-circuitted, no currents will flow into the 4-pole rotor and the 4-pole motor is out of action. The speed then rises to that of the 8-pole machine, 750 r.p.m., and a second speed is obtained without any external losses. This is the elementary form of the two-speed motor.

With the sliprings still short-circuitted and the supply connected to the 4-pole instead of the 8-pole stator windings, the 4-pole machine is alone in circuit and the speed rises to 1500 r.p.m. Three speeds are thus obtainable for the combination. All these effects are obtained in a single machine, as described later, but the principles involved are identical with those of the two-motor combination.

We now come to the Synchronous Cascade Set, in which for the auxiliary 4-pole induction motor is substituted a synchronous motor with a stationary field produced by currents supplied, by an exciter, to the 4-pole stator windings. The set consists of an 8-pole induction motor and a 4-pole synchronous motor, the windings of both the rotors being connected together exactly in the same way as in the induction motor case. The set runs at a synchronous speed of 500 r.p.m. and, as before, the counter E.M.F. in the rotor of the 8-pole induction motor is only two-thirds of the E.M.F. supplied to it by transformer action. The remaining one-third is generated in the 4-pole rotor windings by cutting the stationary 4-pole field of the synchronous machine. The combination is two-thirds an induction motor and one-third a synchronous motor.

The last combination to be described is the Self-paralleling Alternator which, in principle, is identical with the synchronous motor combination. We have an 8-pole induction machine with its rotor windings directly connected to the rotor windings of a 4-pole synchronous machine having a stationary field as in the case of the Synchronous Motor but, as power is supplied to the shaft to drive the set at 500 r.p.m., the combination becomes an 8-pole induction generator with its rotor windings supplied by currents from the rotor of a 4-pole synchronous alternator. The 4-pole rotor windings, cutting a 4-pole stationary field at a speed of 500 r.p.m., have generated in them currents of a frequency of 16⅔ cycles per second and these currents flow directly into the rotor windings of the 8-pole induction generator. Now if the rotors are driven in a clockwise direction, the field, produced by the currents in the 4-pole rotor, must rotate round it in a counter-clockwise direction at 500 r.p.m., so that in space this field is stationary and coincides with the stationary field produced in the stator by the exciting current. As the 8-pole and 4-pole rotor windings, as in the case of the motors already considered, are so connected that the currents in them produce fields rotating in opposite directions, the 16⅔ frequency currents supplied to the 8-pole rotor windings produce a field which rotates in a clockwise direction at 250 r.p.m. As the speed of mechanical rotation is in the same direction and is 500 r.p.m., the 8-pole field rotates in space at 750 r.p.m. (500 + 250) r.p.m. and cuts the 8-pole stator windings at this speed, thus generating in them E.M.Fs. having a frequency of 50 cycles per second.

Figure 2 illustrates the case of the Alternator or Synchronous Motor. The magnetising current of the 8-pole induction generator is supplied to its rotor windings by the 4-pole synchronous machine.

The Single Field Machine.

Each of the foregoing cascade sets consists of two independent machines each having its own core, windings and magnetic field. These have been considered in some detail because it is so much easier to form a mental conception of the way these machines work when so considered, than it is when the two machines are merged into one motor with a single core, flux and windings, as in the machines with which this paper is concerned.

Further, the theory of the single machine is the same as that of the individual machines and the method of calculating the performance curves are the same for both cases.

To produce a single machine which will serve the same purposes as the two independent machines, we require a core capable of accommodating both the 8-pole and 4-pole fields and, on both the stator and rotor, single windings which, when carrying the same currents as were previously carried by the two machines, will give exactly the same distribution of ampere-turns. Supposing we take the windings out of the 4-pole machine and place them in the slots of the 8-pole motor; connect together the terminals of the two rotor windings and couple the starting, or speed regulating, resistances to the terminals of the 4-pole stator winding, we shall then have a Single Cascade Motor, similar in its functions to the individual 8-pole and 4-pole Induction Motor Combination. Such a machine would require deep slots, involving high magnetic leakage, and a great deal more copper than an ordinary machine and so its losses would be large, and efficiency and power factor low. The next step is to substitute, in both stator and rotor, single windings which will give us the same results as the separate ones.

Cascade Windings.

First consider the stator. Here we have an 8-pole winding, carrying 50 cycle currents supplied from the mains, and a 4-pole winding, carrying low frequency currents when the machine is on load. What is wanted is a parallel winding, to the terminals of which the supply is connected, with tappings at points which are at equipotential as regards the supply voltage. Supposing four coils be connected to form a square and at the junction of each pair of coils a terminal be provided, so that there are four terminal points. If two opposite terminals are connected to a supply of electricity, then between the other terminals there will be no difference of potential as each is situated midway between the two supply terminals. We can connect a second supply of electricity between the second pair of terminals and then the currents from both sources will circulate in the same coils entirely independently of one another. If now the flow of the currents is traced it will be found that in two adjacent coils the currents from both sources flow in the same direction, but in the remaining coils the two currents flow in opposite directions. If the coils are arranged on a stator core in such a manner that the current through them from the first source produces dissimilar poles in adjacent coils, the result will be a 4-pole field. The current from the second source, flowing in an opposite direction in two of the coils, will produce a 2-pole field. A stator, shown with salient poles for the sake of clearness, arranged with windings consisting of four coils as described is represented by Fig. 3. The terminals from the first source are marked "Line" and from the second source "Tapping."

This single winding serves the same purpose as two separate 4-pole and 2-pole windings. It has been drawn for this number of poles as the diagram is clearer than for a winding for 8-poles and 4-poles, and equally well illustrates the use of a single winding which is exactly equivalent in its effects to the two separate windings hitherto considered.*

Using the same principle but arranging these coils in three groups to form a Star Connected Winding suitable for a three-phase motor, we obtain the winding shown diagrammatically in Figure 4. In each phase there are two pairs of tappings because the distribution of the currents is more satisfactory than would be the case if a single pair of tappings was used in each.

The Rotor Winding.

We now have to show how the two separate rotor windings of the elementary machine are replaced by a single winding giving the same results. The required winding is to be capable of producing, when currents flow in it, two fields, one having eight poles and the other four poles, rotating in opposite directions. To simplify the diagrams, windings having four poles and two poles will be described, as duplicating these will make them suitable for the larger number of poles.

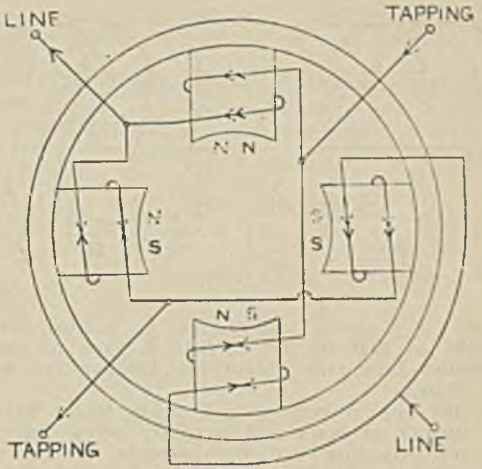


Fig. 3.

The principle of the winding is very simple and can be demonstrated by open-circuitting one slipring of an ordinary induction motor having a star connected rotor. When this is done the rotor winding becomes single phase and, as is well known, a single phase winding produces a field which can be resolved into two fields rotating in opposite directions. These fields have the same number of poles, one rotating in the same direction as the stator field and combining with it, whilst the other cuts the stator winding and induces in it low frequency currents when the motor is running. The machine runs at half its normal speed as it has become a Cascade Motor with main and auxiliary fields having the same number of poles.

It can be shown very simply that a single phase winding is equivalent to two three-phase (or two-phase) windings.

Fig. 5(a) shows two three-phase rotor windings each produching a 2-pole field, the direction of rotation of one field being opposite to that of the other.

In Figure 5(b) is shown the resultant single-phase winding, obtained by adding together the currents in each pair of bars in a vertical line, that is to say, in the same slot. In slots 1 and 4, each conductor carries a current of A phase, and these can be replaced by a single conductor carrying a current, of the same phase, and of twice the amplitude. In each of the other slots there are two conductors carrying currents of phases B and C differing in phase by 120 electrical degrees. The resultant

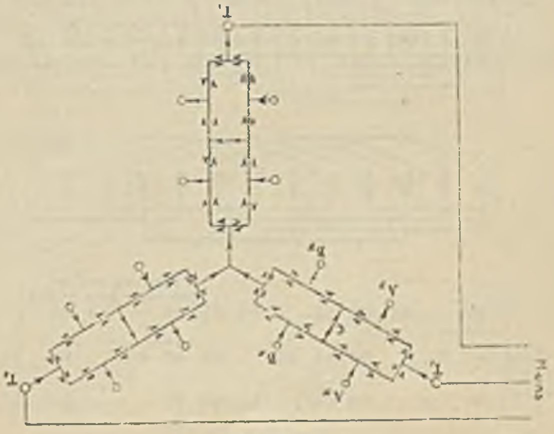


Fig. 4.

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* This method of explaining the Cascade Stator Winding is due to Prof. H. J. S. Heather, and first appeared in *The Electrician,* Vol. 69, pp. 1068-1069.

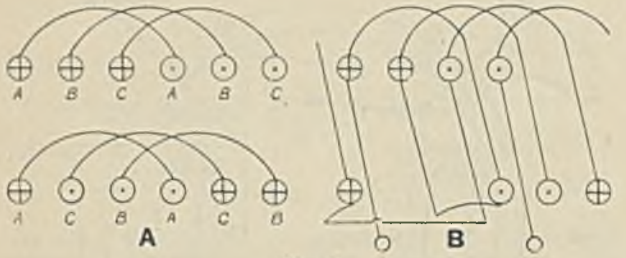

Fig. 5.

of these is a current, of phase A, having the same amplitude as that of the current in each of the bars. Substituting these we obtain the single-phase winding, Figure 5(b).

In the special case of a Cascade Motor having an equal number of main and auxiliary poles, there exists the grave objection that the currents, induced in the stator windings by the secondary field of the rotor, produce the same number of poles as do the currents supplied to the stator from the mains and, therefore, both currents follow the same paths. It follows that, when the motor is running, low frequency currents flow from the stator into the mains.

The practical machine is given pole numbers which differ one from the other, such as 8 and 4, and then the low frequency currents can be confined to paths which do not include the main terminals. These paths are closed by pairs of tappings as shown in Figure 4.

To develop a rotor winding for the eight main and four auxiliary poles we proceed in exactly the same way as for the case just considered.

Figure 6 shows, in the same slots, a 4-pole three-phase winding producing a field rotating in a clockwise direction, and a similar 2-pole winding producing a field rotating in the opposite direction. The 4-pole winding has two bars per slot and the winding pitch is two-thirds of normal. Referring to the figure, in certain of the slots there are bars carrying currents which are opposite in phase and can, therefore, be omitted without affecting the production of the fields. After cancelling these there are left six slots each carrying three bars and an equal number each carrying only one bar. In each of the three-bar slots there are two bars carring currents of different phases, the resultant of which is $\sqrt{3}$ times the current of a single bar. Each of these pairs of bars can be replaced by a single bar, carrying the resultant current, and if these are connected to form a star and the single-current bars a mesh, the two can be coupled together into a single combined Star Mesh Winding, Figute 7. This winding is used for all machines which are not required to run at speeds other than Cascade.

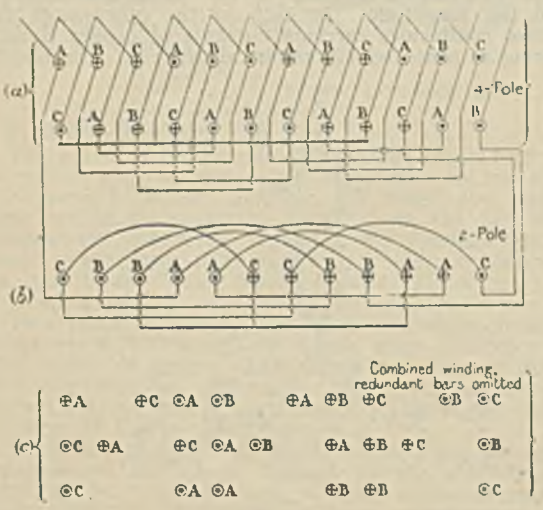

Fig. 6.

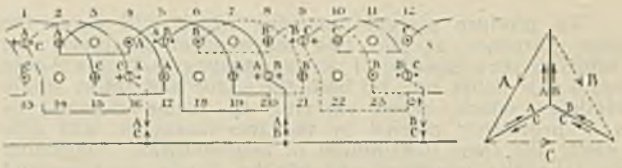

Fig. 7.

These single stator and rotor windings give exactly the same current distribution as the double windings with this important advantage that they can be accommodated in much shallower slots and therefore produce considerably less magnetic leakage. Further the copper losses in them are very considerably less than in the double windings.

Two or Three Speed Rotor Windings.

In order to make the windings suitable for other speeds it is only necessary to make such a change in the connections that they are no longer capable of producing the auxiliary field.

It has been mentioned that if the brushes are lifted off one of the sliprings of an ordinary induction motor, the rotor develops a second field and the machine becomes a cascade motor running at half normal speed. To suppress the second field, and therefore to cause the machine to run at full speed, it is only necessary to bring into use the whole of the windings by connecting all the sliprings together. The same principle applies to all cascade windings. In the winding, Figure 7, six of the slots carry only one bar. In order to suppress the cascade field these slots must be filled and connected to the remaining windings in such a manner that the whole becomes a symmetrical winding with currents of the same amplitude in each bar.

Figure 8 shows this winding and the distribution of the currents in it. The half empty slots are filled with coils each of which is connected at one end to the centre point of one of the sides of the mesh winding and at the other end to a slipring. The winding produces four poles with the sliprings short-circuitted and four poles and two poles when they are disconnected. By duplicating the winding it is made suitable for eight poles and four poles.

Three Speed Rotor.

To obtain a third speed, the stator winding is divided and reconnected for half the number of poles. The rotor winding requires no alteration, the currents distributing themselves as shown in Figure 9 and producing two poles.

For a practical machine the winding would be duplicated, the number of poles available being 4, 8, and 12 (8 + 4), corresponding to speeds of 1500, 750, and 500 r.p.m. at 50 cycles.

The distribution of the rotor currents, it will be seen, differs materially in each case. When running at full and cascade speeds the bars in the Star sections of the winding carry currents the amplitude of which is $\sqrt{3}$ times that of the currents in the Mesh sections, as each is the resultant of two Mesh currents differing in phase by 60 electrical degrees. When running at half speed the currents in both the Star and Mesh sections are of the same amplitude for at each point of interconnection three currents meet which differ in phase by 120 electrical degrees, and the resultant of any two of these has the amplitude and phase of the third.

Below the winding diagram of Figure 9 is shown the equivalent current distribution in the slots. This is obtained by substituting, in each slot, a single current which is the resultant of two component currents.

This completes the description of the windings for all types of Cascade Induction Motors.

There only remains to be explained the Stator Windings for Cascade Alternators and Synchronous Motors as the short-circuitted type of rotor is used with both these machines.

Fig. 8.

Self Parallel Alternators.

A different type of stator winding is required for this machine as it has only to carry the exciting current in addition to the alternating output currents. The simplest winding for the purpose consists of two Star connected groups of coils in parallel, the exciter being connected to the two neutral points.

This winding will be readily understood from the diagram Figure 10. The developed winding is shown with slots numbered 1 to 12 and below it a key diagram. In each slot there are two conductors, or coil sections, the direction of the three-phase currents at a particular instant being indicated by crosses and dots. Outside each circle the direction of flow of the exciting currents is shown. It is a 4-pole three-phase winding with exciting currents producing two poles. The coils span two slots, the normal pitch for a 4-pole winding, and in half of the slots the exciting currents cancel and are ineffective. By increasing the throw of the coils so that they span three slots, the exciting current is effective in two-thirds of the slots and this is, generally speaking, about the best pitch to use.

It will be seen that paths are available through the exciter and also between the phase windings themselves for the flow of currents induced during paralleling or by change of rotor speed. As the whole of the stator winding is available for these currents, very effective damping is obtained.

This type of winding cannot always be used, as large low voltage machines with windings having only a few bars per slot would require a larger exciting current than is convenient. To meet such cases, the exciting current can be reduced, for example to a half by using a second pair of parallel connected star windings used only to carry the exciting current.

The key diagram for such a winding is shown in Figure 11. Windings of this type are convenient for, as the corresponding bars in each Star section lie side by side in the same slot and are at the same potential, they can be made up into single coils without requiring additional insulation between them.

Stator Windings for Synchronous Motors.

These are similar to those of the alternators excepting that one of the Star sections is opened to enable a three-phase resistance to be connected in circuit for the purpose of starting. One of the exciter terminals is connected to the unopened neutral point and the other to the neutral point of the starting resistances. When the resistances have been short-circuitted, the connections are identical with those shown in Figure 10.

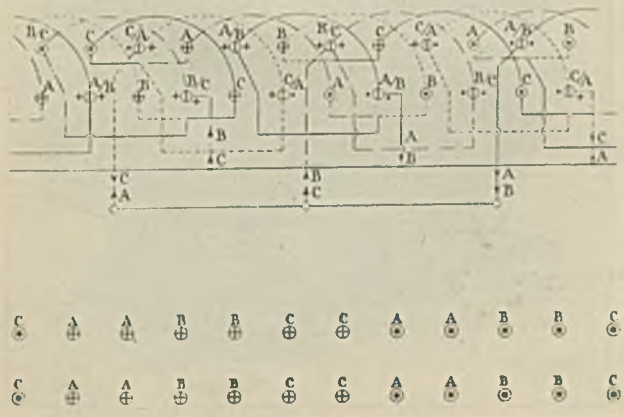

Fig. 9.

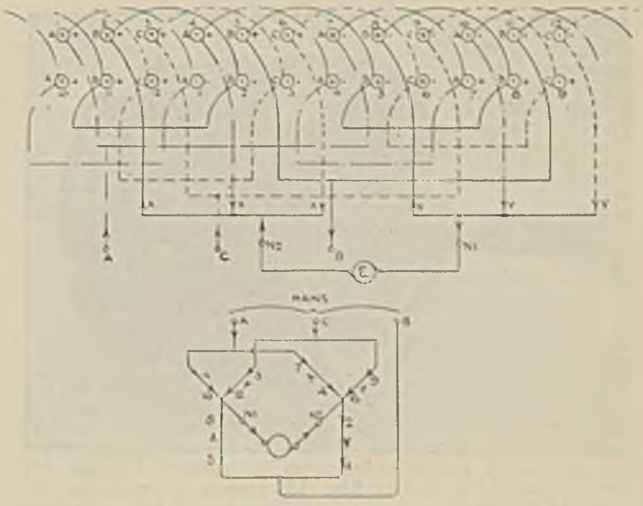

Fig. 10.

Creedy Motors.

This section of the paper would not be complete without a reference to Mr. Creedy's work in developing rotor windings which make possible the building of cascade machines for speeds other than those that can be obtained with windings of the type which have been described. Mr. Creedy has discovered that the Star Mesh type of winding for three-phase currents, the type already described, is only one example of a new class of windings characterised by the Star Mesh System of groupings.

If the windings of Figure 8 are examined it will be seen that, if each coil is given the number of the slot in which, say, its top half is situated, then the mesh section of the winding consists of all the even numbered coils connected in a regular sequence, adjacent coils always having their top sections connected together and their bottom sections so connected. The Star sections are the odd numbered coils and they are connected to the Mesh sections in their correct sequence; for example, the bottom of Coil 3 to the tops of Coils 2 and 4, and the bottom of Coil 1 to the tops of Coils 12 and 2.

To reduce the diagrams to their simplest forms only one coil per pole per phase has been shown. In an actual machine with three or four coils per pole per phase each coil of the diagram must be taken to represent a group of three or four coils as the case may be.

The diagrams should have twelve coils or sections for a 6-pole (4 + 2) cascade rotor or two sections per pole. This is typical of all cascade windings.

Mr. Creedy has described motors with different pole combinations, for example, an 8-pole Cascade Motor

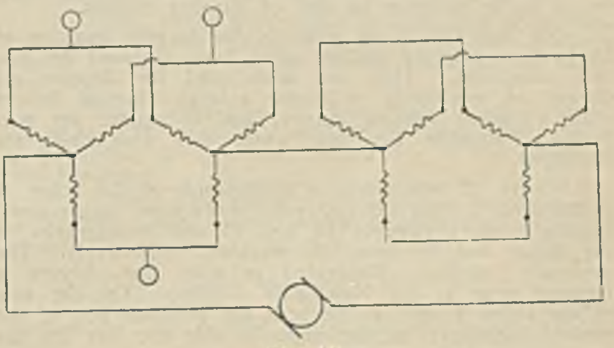

Fig. 11.

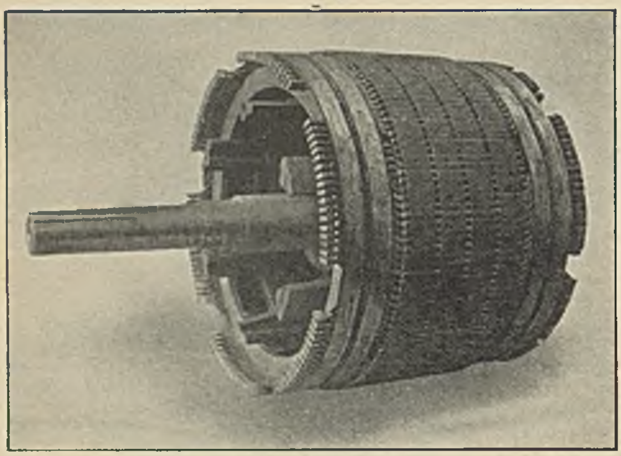

Fig. 12

having six and two poles. Following the rule already mentioned the rotor winding has sixteen groups of coils connected to form a Mesh Winding of the groups of coils having even numbers. The diagram forms a square. If required to serve as a two-speed rotor, there will be eight groups of Star Connected Coils, four symmetrically spaced being connected to a common neutral and the remaining four, to sliprings. If required to run only at cascade speed these last sections will be omitted.

Following the same rules windings for any pole combinations can be developed, the only limitation imposed being that the difference between the two numbers of poles must be greater than two. This requirement must always be met in order that no unbalanced magnetic forces shall exist.

Mr. Creedy has fully described these developments in a paper read before the Institution of Electrical Engineers; it has only been possible to refer briefly to them here. We will now return to the machine developed by the Author.

CHARACTERISTICS OF THE CASCADE MACHINE.

One-Speed Motor.

These are the same as for an ordinary slipring motor. The starting torque and speed are controlled by resistances connected to the stator tappings, the rotor windings are subjected to very low voltages and are completely short-circuitted. When standing, with the tappings open, a motor takes only its open-circuit current and develops full load starting torque when taking approximately full load current. Its speed can be controlled, by the stator resistances, down to creeping speeds as low as 2% of full speed. This type of motor is used in collieries and quarries for driving haulage gears, the control of speed and starting torque having been found to be superior to that of slipring motors.

For this reason, in some of the largest quarries in Derbyshire, slipring motors have been replaced by cascade machines. They are also used for driving all classes of machinery requiring a large starting torque with a limited starting current and of course are particularly suitable for use when dirt and dust are prevalent.

Figure 12 reproduces a photograph of the rotor of a 200 B.H.P. 3300 volt, 50 cycle, 490 r.p.m., single-speed cascade motor; Figures 13 and 14 are photographs of the stator and the complete machine, respectively. The particular machine illustrated is used for driving a haulage gear at the Newdigate Colliery. On the side of the stator frame can be seen the terminal box of the control tappings; on the opposite side the box for the main terminals is mounted.

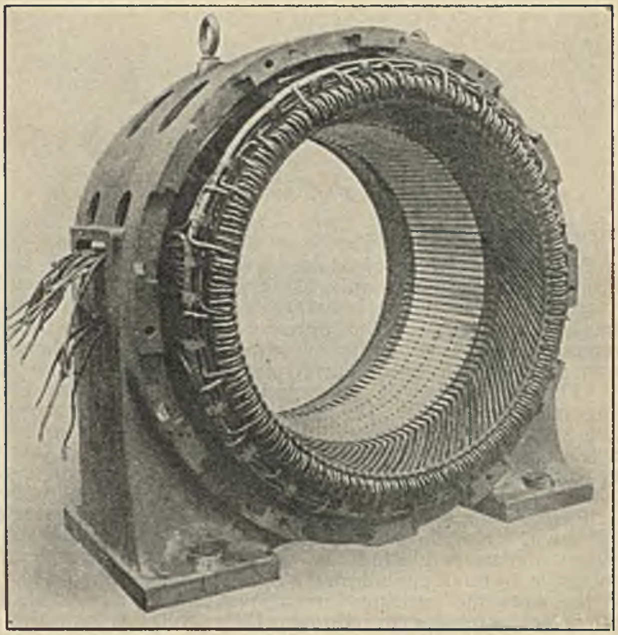

Fig. 13

The illustration, Figure 15, is of a 300 B.H.P., 3-phase, 50 cycle, 400 volt, 490 r.p.m., cascade induction motor, which drives a crusher at the Hillhouse Quarries, Troon, Ayshire.

Two- and Three-Speed Motors.

When intermediate speeds or speeds lower than that corresponding to cascade are not required a switch for short circuitting the stator tappings can be mounted on the side of the stator frame to close the tappings. The motor being always started by resistances connected to the sliprings; if full speed is required the machine is started in exactly the same way as an ordinary induction motor; when second speed is required, resistances are cut out

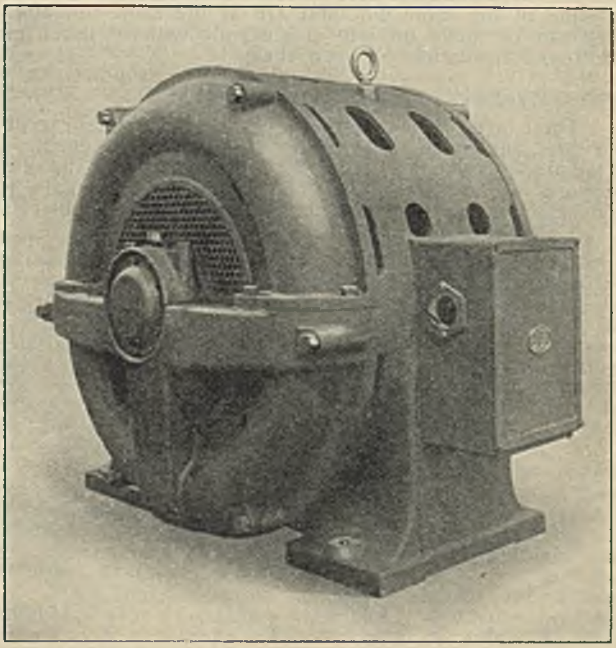

Fig. 14.

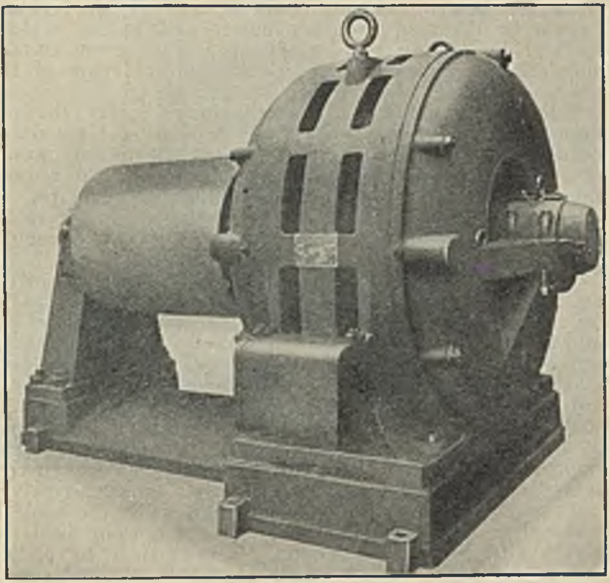

Fig. 15.

of the rotor circuits until approximately the second speed is reached and then the stator tapping switch is closed and the sliprings open-circuitted. In the case of a three-speed motor, a change-pole switch is also mounted on the stator and is set for full or half speed before the machine is connected to the mains.

Three sliprings are used for both two- and three-speed machines. Three-speed motors are wound for speeds in the ratio of 6 : 3 : 2 ; for example, 1500, 750, and 500 r.p.m.; or 1000, 500 and 333 r.p.m. Two-speed machines can be wound for speeds in the ratio of 3 to 2 or 3 to 1; for example, 750 and 500 r.p.m.; or 750 and 250 r.p.m. When intermediate speeds or lower speeds are required by resistance control, all the switchgear can be combined in a single controller which is used for starting as well as speed controlling.

In collieries two- and three-speed motors are used principally for driving ventilating fans and air compressors and, in special cases, haulage gears. Their application to the driving of winding engines is dealt with in a separate section of this paper. The two-speed machine, wound for speeds in the ratio of 3 to 2, is particularly well adapted for driving colliery fans as the lower speed is generally sufficient for week-end working. It is designed to work with the stator windings connected in "mesh" for full speed, and in "star" for the lower speed, in order to keep up the efficiency and power factor with the reduced output, which is generally only about 30% of that at full speed.

(*To be continued.*)

NORTH WESTERN BRANCH.

Systems and Economic Results of Power Factor Correction.

H. S. CARNEGIE.

(*Paper read in Wigan, 25th November,* 1929.)

SUMMARY.

Preliminary considerations of power factor in A.C. systems.

The effect on users under different conditions of power supply.

Methods of correcting power factor and choice of method to be adopted.

PRELIMINARY.

Bad power factor is, in the main, due to machines of the induction type running at low speed and at much under the rated output. If synchronous machines of the salient pole type could be used for all electric drives, then the question would not arise since they could all be of unity or leading power factor. Unfortunately they cannot always be used since they suffer from the disadvantage of a low starting torque and cannot be used where any variation of speed is required. Alternative types of synchronous motors are now available which have high starting torques, but they are still not suitable for intermittent or reversing drives, nor for drives where the use of a flywheel requires a variation of speed with load.

In addition the synchronous motor is dearer than a plain induction motor, and, on account of the simplicity and cheapness of the squirrel cage and slipring induction motors, they will continue to be used. In a normal induction motor, the magnetic flux is supplied from the line and is of such a value as nearly to balance the applied voltage. The current which flows through the windings to supply this magnetism is almost entirely inductive and therefore lags behind the voltage by practically 90 degs.

The wattless K.V.A. taken by the motor is naturally high since it is the product of the *applied* voltage times the magnetising current. This wattless K.V.A. is proportional to the frequency; so, for example, a motor operating on 440 volts 50 cycles has twice the wattless K.V.A. of the same machine working on 25 cycles, since in the latter case 220 volts will cause the same magnetising current to flow as 440 volts will at 50 cycles.

If the magnetism is provided by direct current such as is done with a synchronous motor, then the exciter has only to cover the copper losses of the exciting circuit, and since there is no reactance at zero frequency, the D.C. exciter is very much smaller in K.V.A. than corresponds to the wattless K.V.A. which would be supplied from the line to magnetise the stator to the same amount.

Instead of magnetising the machine from the line, or by making it a synchronous machine with direct current, the magnetism can be provided by currents of the frequency of the rotor by means of the phase advancers, compensators or A.C. exciters.

Since the frequency of the rotor is of the order of 1⅓/2 cycles for a 50 cycle machine, it follows that the impedance of the rotor circuit is low, and consequently the phase advancer needs only to have a small pressure to force the magnetising current through the rotor circuit. Therefore the K.V.A. capacity of such an exciter will be very much smaller than the wattless K.V.A. which it corrects for, although not so small as a D.C. exciter.

In addition to the above methods of power factor correction, we may take an induction motor and let it draw the magnetising K.V.A. or lagging K.V.A. from the line; then neutralise this lagging K.V.A. by installing static condensers which take leading K.V.A. from the line.

Apparatus for improving power factor therefore falls into three classes:—

1.—Static condensers which provide a leading wattless current at *line* frequency to counter-balance partly or wholly the lagging wattless current taken by the induction motor.

2.—Phase advancers or compensators which enable the motors to work at round about unity power factor by providing the necessary magnetism at *low* frequency into the rotor.

3.—Synchronous machines which can work at unity or leading power factor, which provide the magnetism at *zero* frequency, i.e., by direct current.

The effects of the bad power factor are:

(*a*) Extra heating of motors due to the wattless current as well as the wattful current flowing in the stators.

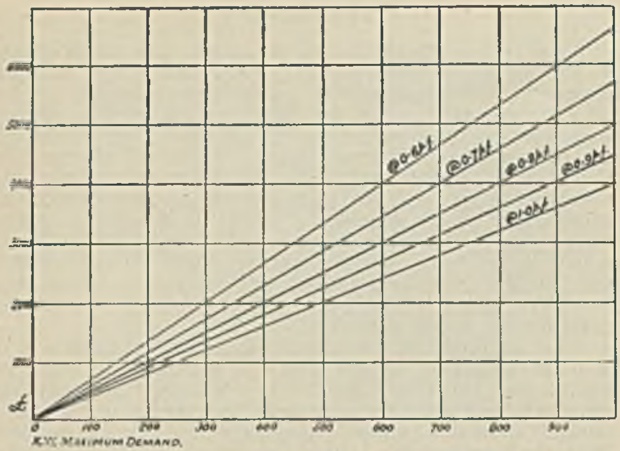

Fig. 1.

(*b*) Extra heating in the transmission system due to the extra wattless current.

(*c*) Extra pressure drop in the transmission and distribution system due to the larger current carried and the inductance of the system. This also reduces the illumination and the motor overload capacities.

(*d*) Extra heating in transformers and switchgear again making them more expensive than for better power factors.

(*e*) Extra heating of the generating plant due to a heavier wattless current flowing.

(*f*) Extra excitation current required on the generators due to the lagging current exercising a de-magnetising action.

(*g*) Extra fuel required in the generating station, because of the above losses.

Consequently a bad power factor has sooner or later to be paid for and although there are numerous cases where power contracts are still in existence without any penalty for bad power factor, or bonus for good power factor, these contracts are only renewed where the system has not been loaded up sufficiently to make the extra heating serious.

In other cases power supply authorities have had to increase their charges to customers, or to modify their contracts so as to penalise a customer with a bad power factor, and give a bonus for good power factor.

Value of Improvement in the Power Factor of an Installation.

There are in general three classes of users:

1. Those who buy power from an outside source on a flat rate per unit with or without a maximum K.W. demand charge but with no penalty or rebate on power factor.

2. Those who generate their A.C. power in their own power stations.

3. Those who purchase power at a definite rate per unit plus a penalty or rebate on power factor or with a maximum demand charge based on total K.V.A.

Power Purchased at Flat Rate.

Although a user who purchases power under Condition 1 has no apparent incentive to improve his power factor, occasionally he may on application secure better terms for doing so.

In addition where his distribution system is lengthy and a low voltage is used, he may very often suffer from bad voltage regulation and be incurring extra losses in this distribution system which could be reduced with a better power factor. Further, a better power factor will obviously give him a more constant supply voltage from the power company and so even if his lighting system be divorced from his power distribution system, he will be getting the benefit of a more even voltage supplied to him by improving the power factor of the power company's transmission system.

It cannot of course be said in all cases that an improvement in his power factor will bring his voltage regulation within the close limits which he would desire, as other causes may be operating which require the use of say an automatic induction regulator to effect this. Undoubtedly, however, a better power factor will result in better voltage regulation. An example will be instructive on the above.

A user supplies a load 400 yards away by a 0.5 sq. in. 3-core buried cable carrying 500 amperes, the voltage received from the supply company being 440 and the system three-phase 50 cycles. The load has a power factor of 0.7 and the voltage at the receiving end will consequently be in the neighbourhood of 413 volts while the loss in the cable itself will be 15.0 K.W. which, if operating for say 3000 hours per annum at 1d. per unit, amounts to £188 per annum. If we can improve the power factor to 0.95 lagging, the current is reduced to approximately 368 amps. and the received voltage is increased to 423, while the loss in the cable is reduced to 8.2 K.W. which costs on the same basis as above £103 0s. 0d. per annum. Consequently by installing power factor improvement apparatus, the voltage is increased and therefore better illumination and greater overload capacity of the motors is obtained and the cost of power per annum is reduced by £85 0s. 0d.

If in addition there is a maximum demand charge this will be reduced by say 7.0 K.W. which at £6 0s. 0d. per K.W. per annum amounts to another £42 0s. 0d.

There is therefore a direct saving of £127 0s. 0d. with maximum demand K.W. system of charging and if the user can secure a rebate for his better power factor it will certainly be worth his while looking closely into the question.

Power Generation on Site.

If the user generates his own power the result of a bad power factor will not only be to give extra heating and losses on his cables, transformers and switchgear, but he will also be up against the effect in his generating station.

With a turbo driven plant, the results of a low power factor will be that the stators have to carry extra current and so are heated more than they should be. They are normally designed to carry their full load at 0.8 power factor so that a power factor of 0.7 will decrease the K.W. loading of the machine by about 15% and the turbine can not be utilised for its full output.

Alternatively with full K.W. on the turbine, the heating on the stator copper at 0.7 power factor will be 20% to 25% greater than at 0.8 power factor.

For the same stator current and terminal voltage the K.W. lost in exciting the rotor may be 10% greater at 0.7 power factor than at 0.8 power factor.

The turbine is generally designed with the most economical consumption at ¾ load, and at 0.8 power factor it can work comfortably at this load and still leave a nice margin for load variations. At 0.7 power factor, however, it can hardly work up to its economical consumption and for the same K.W. load another set has to be run, either to act as a synchronous condenser or to share the load, and it will take 15% to 20% of its full steam consumption to run even at no load.

In addition, as has been shown above, for the same voltage at customers' terminals at 0.7 power factor, the power station will require a higher voltage than at 0.8 and so still more excitation. To provide for more excitation with the possibility of running another unit, also to cover the extra losses in the stator, and transmission losses, the fuel consumption must be higher, say 3% to 5% more. This is very serious in view of the long hours worked per annum. The cost of power generation in a private station is divided in many different ways over the various departments, but in any case the engineer in charge should penalise any department responsible for his increased costs due to bad

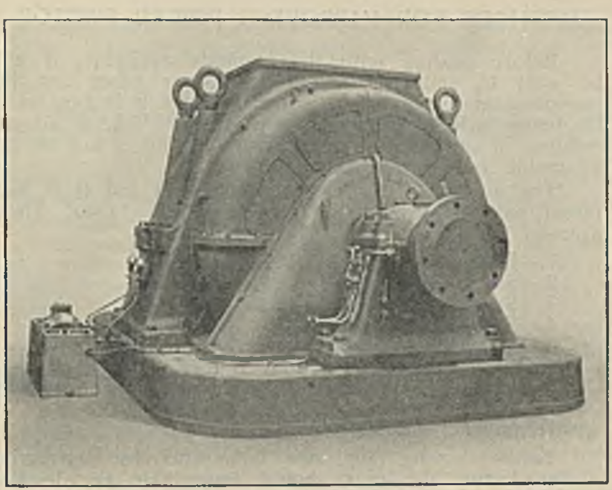

Fig. 2.—A 6500 K.V.A., 750 r.p.m., 11,000 volt Synchronous Condenser.

power factor. It is obvious that this case approaches that where power is purchased and a bonus or penalty added to power charges on account of power factor.

Power Purchased on part Power Factor or K.V.A. Basis.

As so many users come under this heading, it is proposed to deal more completely with this case. A popular tariff is one where there is a charge per unit and a quarterly or annual charge per K.V.A. of maximum demand, often amounting to £4 0s. 0d. per K.V.A. per annum. Obviously, the effect of a bad power factor not only effects the units consumed by increasing the losses on the distribution system, but also increases the maximum demand in K.V.A.

A glance at Figure 1 will shew the annual maximum demand cost on the basis of £4 0s. 0d. per K.V.A. per annum. If the maximum demand be 500 K.W. at 0.7 power factor, then the K.V.A. is 714 K.V.A., and the annual charge is £860 0s. 0d. per annum. If the power factor be increased to 0.8, the charge would be £500 0s. 0d. or a saving of £360 per annum. Now the wattless K.V A. saved equals 125 and since the cost of improvement on a 50 cycle system should certainly be less than £3 10s. 0d. per K.V.A., say £438, it is obviously well worth while improving by this amount.

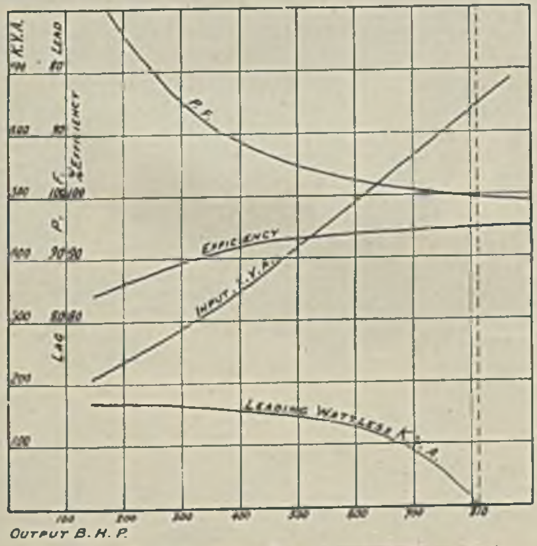

Fig. 3.—Performance Curves of Salient Pole Synchronous Motor.

The question then arises as to how far correction should be carried. The answer is that the cheaper the power factor correcting apparatus, the nearer to unity can the power factor be corrected and still give an attractive proposition.

Using the above example and still assuming the cost of power factor improving apparatus to be £3 10s. 0d. per K.V.A. (which will not only cover the extra cost of synchronous machines or power factor compensators, but also static condensers), and allowing 12½% for interest and depreciation on capital cost, also 2% extra loss for extra power to drive the compensator working 3000 hours per annum at 1d. per unit, the following table is derived:

Power Factor Corrected to	*Annual Saving*	*Capital Cost*	*% return on outlay*
0.7	0	0	—
0.75	182.5	210	74.5
0.8	344	438	66
0.90	608	900	55
0.95	718	1172	48.6
1.0	797	1750	33

It is, of course, not always necessary to assume that even 2% loss is incurred in correcting power factor, since in some cases energy will actually be saved; but the above can be called a reasonable example and shews that with this method of charging it will often pay to correct right up to unity, but it will be very attractive to get up to 0.9 lagging.

Should the power factor be lower than mentioned above the reward will be still greater, but if the existing power factor be above 0.8 then the installation is not so bad, and while it should really pay to correct the power factor the result would not give such a big return unless cheaper power factor correction devices are available.

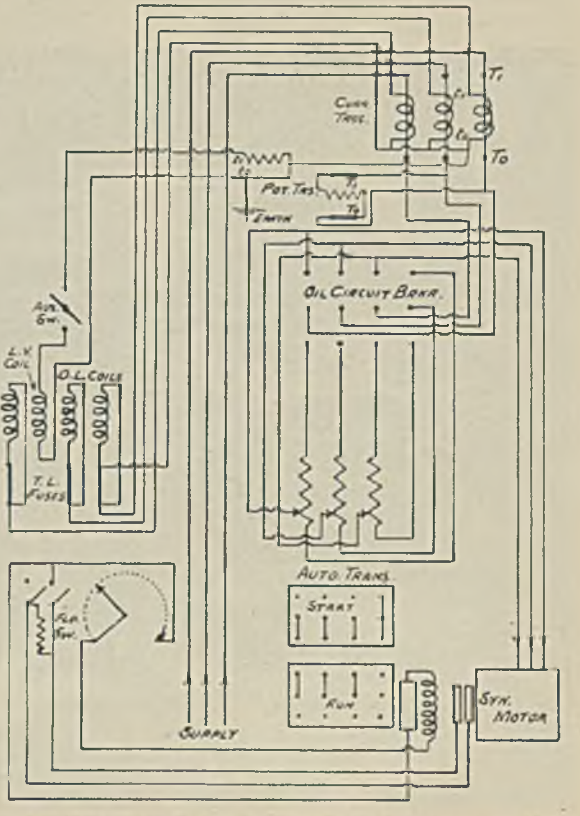

Fig. 4.—Connections for Salient Pole Synchronous Motor.

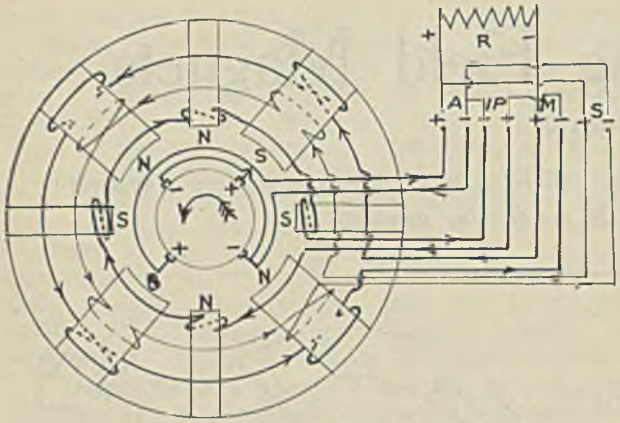

Fig. 3.

Interpoles or Commutating Poles.

These auxiliary pole-pieces are fitted to nearly all modern machines, generators or motors, as shown in Fig. 3. The polarity of the main poles and interpoles of a generator is arranged so that the conductor on the armature passes from under a south main pole to a north interpole as in Fig. 3. These interpoles or commutating poles are wound with a coil which carries the main current. They are for the purpose of improving commutation, so that the generator can work sparklessly at all loads within its rated range without any movement of the brushes backwards or forwards being necessary to suit the fluctuations of the load. The connections for short shunt should be made as shown in Fig. 3. If variable voltage is required a variable resistance should be coupled in the shunt circuit for this purpose.

The E.M.F. of a Generator.

The general formula for the E.M.F. of a generator is

$$\text{The average pressure in volts} = \frac{\varnothing Z n}{10^8} \text{ volts}$$

where $\varnothing$ = the number of lines of force cut by each conductor in the armature per revolution.

n = the number of revolutions per second.

Z = the number of conductors in series with the brushes.

$\varnothing$ varies as the ampere turns, that is, the current multiplied by the number of turns on the pole pieces. It follows, therefore, that with an increase of current in the field coils, an increase takes place in the generated E.M.F.

The flux or number of lines of force is dependent upon (a) the permeability or specific magnetic conductivity of the material of the pole pieces and the core of the armature; (b) upon the area of the pole pieces; and (c) the length of the path the lines of force have to traverse.

The Losses in a Generator.

Generator Losses may be classified under four heads, (1) the mechanical losses, friction and windage in the machine; (2) Losses in Field Excitation; (3) Losses in the Iron of the pole pieces and armature; (4) Copper Losses in the armature.

Friction takes place between the shaft and the bearings (this is very small in the modern machine) and between the brushes and the commutator. Windage, or friction of the air surrounding the rapidly revolving armature, while it is a loss is extremely beneficial in that it helps to reduce the temperature rise of the machine caused by the heating effect of the current passing through the windings.

The loss in the field excitation is entailed by sending a current through the resistance of the field coils and is dissipated in heat. The loss can be easily calculated from the current and the resistance of the wires. The loss in watts is equal to the current squared, multiplied by the resistance; the resistance is a variable quantity which increases as the temperature of the coils rises.

The iron losses are due to eddy currents and hysteresis in the iron of the armature core, this is reduced by the use of thin sheet stampings, laminations, insulated from one another. The hysteresis is due to the reversals in direction or alternations of the magnetic field.

The copper losses in the armature are heating losses due to the current flowing through the resistance of the armature windings.

Of the total losses in a generator, the friction, field excitation, and iron losses, are termed constant losses, as they are approximately the same whatever may be the load or current delivered by the machine, so long as it runs at normal voltage and speed. The loss in the armature winding is nil when no current is delivered, increasing with the square of the current delivered.

WORLD POWER CONFERENCE.

The Second World Power Conference will be held in Berlin from June 16th to 25th, 1930. The development of power supply and power utilisation is the main subject around which discussion will centre at the 1930 conference. The opening ceremony will take place in the premises of the State Opera House (Kroll) and the general conference meetings will also be held there. The offices of the conference will be at the Ingenieurhaus, the headquarters of the Verein Deutsche Ingenieure. In addition to the general sessions, a number of social arrangements have been planned. Before and after the conference visits to the most important German industrial centres will be made. The conference will be presided over by an honorary committee, at the head of which is His Excellency Staatsrat Dr. Oskar von Miller, the pioneer of electricity supply and founder of the German Museum. The honorary committee is composed of representatives of the German Federal and State Governments, municipal corporations, the leaders of German industry, and representatives of German science of international reputation.

PERSONAL.

Mr. G. R. T. Taylor has resigned his appointment as Deputy Chairman of Vickers Limited, but retains his seat on the Board. Mr. G. G. Sim, C.S.I., C.I.E., has been appointed Deputy Chairman in his place. Mr. J. Reid Young, C.A., has been appointed Secretary to the Company in place of Mr. Sim.

Proceedings of the Association of Mining Electrical Engineers.

DONCASTER SUB-BRANCH.

Chairman's Address.

C. WHITEHOUSE.

(*Meeting held October 26th,* 1929.)

When this Association was inaugurated 21 years ago Doncaster probably had two or three members. Since then the increase of membership in this district has been slow, but never-the-less sure. The meetings of the Yorkshire Branch are held in various centres which of course is quite a right system, but there was always the difficulty that a large proportion of members from this part found it impossible to attend the meetings regularly, as it often meant the whole of Saturday afternoon and evening being given up for a 1½ hours' meeting. However, the great necessity was acted upon by Mr. Bleach, and the result was the Doncaster Sub-Branch was formed and received the sanction and blessing of the A.M.E.E. Council. This advance immediately brought new members, apart from those who transferred from the parent Branch, with the result that there are at present about 60 members of the Sub-Branch which is a very satisfactory number. Mr. Bleach was elected our first Chairman, and Mr. Morris, the Secretary. Mr. Morris is still carrying on, with the assistance of Mr. Bunny, and great credit is due to Mr. Bleach and Mr Morris for the way they carried through the first and most difficult period of our history. Mr. Wadeson was our Chairman last year, and he not only carried out his duties as Chairman with great distinction, but he gave some very interesting addresses; it was sincerely to be hoped that he would continue his helpful work in a similar way.

With regard to the programme for the Session, it does not matter greatly whether contributions are in the shape of papers, addresses or discussions, so long as we get them. Things that may seem of little interest to one's self often prove to be of outstanding value to others, therefore, any member with notes of interest should broadcast them at the meetings. Then again any member with a difficult problem to face should bring it here for discussion; he will benefit, as well as his fellow members. There is that little proverb " If you have knowledge let others benefit by it ", which might well be the motto of the Association.

Any member or associate may qualify for the Association Certificates, and I would strongly advise them, particularly the younger members, to prepare themselves and sit for these examinations. The Certificate issued by the Association is a proof of training and a valuable asset to any member; moreover, it may be in the near future recognised by the Home Office. In any case there is no doubt that the Colliery Electrical Engineer henceforth must be able to show some certificate of qualification, and he could not have a better than the first-class certificate of the Association of Mining Electrical Engineers. I hope at the next Examination to see that quite a number of our Branch members have presented themselves and been successful.

With regard to visits during the Summer months, I would like to mention that last Session we had two or three very successful and interesting visits, and our thanks are due to the firms whose works and pits we visited. We hope to be able to arrange similar visits next Summer, and hope members will endeavour to take part in these, as they are most interesting and instructive. Visits are perhaps rather like a busman's holiday, but even the busman picks up quite a lot when riding on top of the bus, instead of driving same.

Mr. BLEACH proposed a hearty vote of thanks to the Chairman.

Mr. H. MORRIS seconded the vote, and, Mr. Whitehouse having suitably acknowledged the compliment, the company proceeded to enjoy a Smoking Concert.

WARWICKSHIRE & SOUTH STAFFS. BRANCH.

Presidential Address.

A. HULME.

(*Meeting held September 26th,* 1929.)

In the course of his inaugural address Mr. Hulme thanked the members for the honour they had conferred on him and said he would earnestly endeavour to justify his election as President of the Branch. He had not prepared anything in the nature of a technical address but would confine himself to a few observations regarding the Association, and more particularly would he speak to the younger and new members. It was very important that all members should be conversant with the principle objects of the Association, as clearly and definitely set out in the Articles of the Association.

He hoped that the younger members would take advantages of the opportunities afforded them and submit their experiences and personal observations in the form of Papers and by taking part in the discussions. He would particularly impress upon young members, who were often nervous in regard to speaking at meetings, that they would receive the very greatest encouragement and help. The older and more experienced members were always prepared to encourage the beginner in every way possible. After all, everyone must make a start and those experiences which appeared difficult to the junior member would often be found to have been met and overcome by those of wider experience. He himself had joined this Branch during its first year, and so had been able to watch its successful progress. The members' deliberations had been very helpful in the way of developing the use of electricity in mines, and in directing the improvements in such apparatus as switchgear control, motors, and cables for mining service, which now reached a very much higher standard of reliability than was the case in the early days of the Branch; he felt justified in claiming that such an advanced degree of development was in no small measure due to the efforts of the Association. He felt considerable gratification in his long association with so successful an organisation.

With the rapid development and increasing importance of power installations in coal mines, electrical motive power being the most efficient would inevitably displace other forms of power; as well as for the great reason that its flexibility lends itself readily applicable to all power requirements. With the increasing need for electrical machinery at the coal face, the duties and responsibilities of the electrical engineer and staff were daily becoming more complicated and strenuous. It thus devolved upon the younger members to obtain sufficient knowledge, to enable them to perform their duties with confidence from an efficient and safety point of view in the control and maintenance of the mining electrical

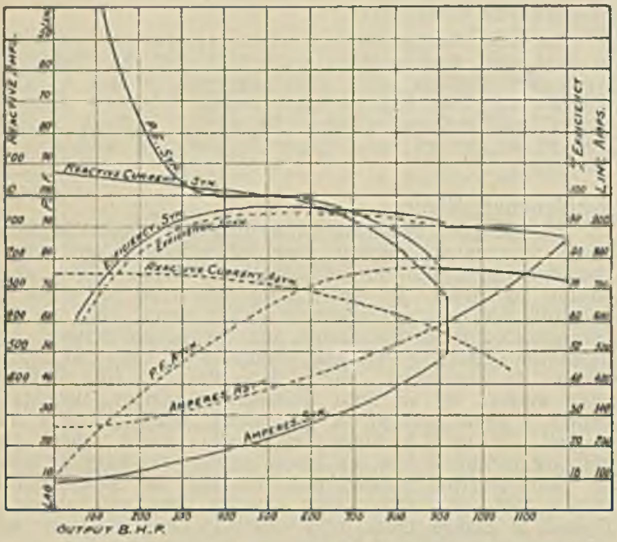

Fig. 7.—Performance Curves for 550 *H.P. Asynchronous Synchronous Motor.*

Synchronous induction motors or asynchronous synchronous motors have now been in use for some years to give the starting torque of an induction motor and the advantage of unity or leading power factor operation of asynchronous-synchronous motors. These are similar to induction motors, but designed to permit the direct current from the exciter to flow through the rotor. They allow of gradual starting like an induction motor by the use of rotor resistance, but instead of having one point of maximum torque they have two, the first being the pull-out point as a synchronous motor, after which they will run asynchronously like an induction motor with a further pull-out point.

The illustrations, Figures 11 and 12, shew the use of these for typical drives. They are suitable, in fact, for nearly all drives of constant speed, where stopping is not frequent. If they are to be stopped frequently, then an induction motor should be used either plain or with a compensator and, if necessary, improve the power factor elsewhere, on continuously running motors. They are naturally most efficient at unity power factor, have a larger air gap than induction motors but smaller than salient pole machines, are not so suitable for very leading power factors, but have been used to 0.6 leading.

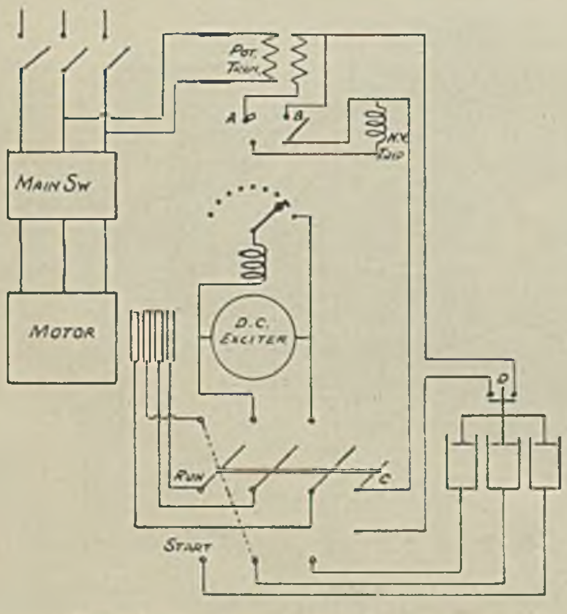

Fig. 8.—Connections for Asynchronous Synchronous Machine.

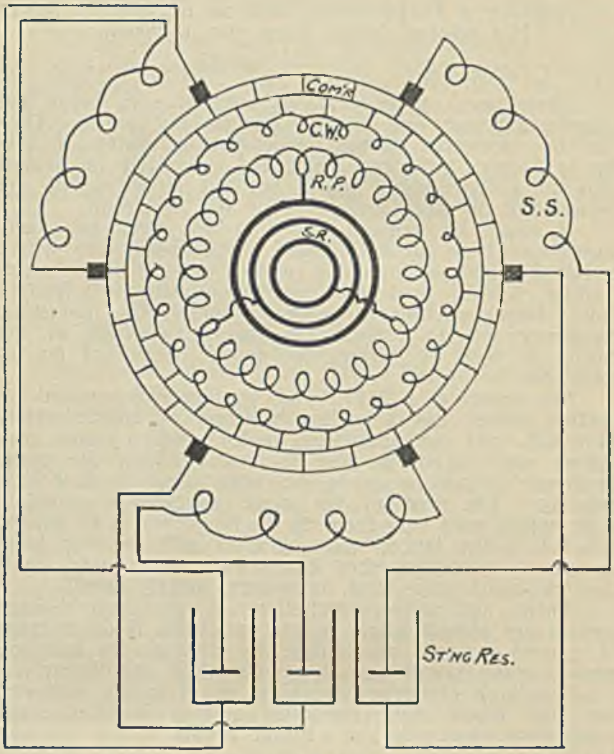

Fig. 9.—Connections of "Kosfi-Leading" Motor.

The starting gear is simpler than for a salient pole and cheaper. Figures 4 and 5 shew, respectively, typical performance curves and diagram of starting gear.

The salient pole motor and control comes to about the same price as an asynchronous-synchronous motor and control. Compared with an induction motor, either of the above types of synchronous motors will give the power factor correction for £2 0s. 0d. down to 10s. 0d. per wattless K.V.A. lagging saved and so either will be very attractive for power factor correction. For machine drives smaller than say 150 H.P. to 200 H.P. alternative corrective devices described later are more attractive.

Converting Plant.

Where direct current is to be obtained from A.C., the correcting plant offers a favourable opportunity for correcting the power factor. Obviously the most efficient

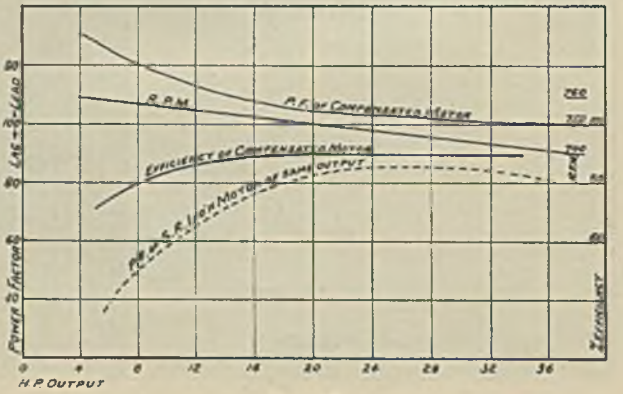

Fig. 10.

rotating correcting plant will be a rotary or motor converter, but in these cases it is not practicable to work at a very leading power factor as the output of the frame and the efficiency falls away. The fact that they work at unity power factor will, however, improve the power factor of the whole system, but will not reduce the wattless K.V.A.

Where motor generator Sets are used, the driving motor should, for small sets, be a compensated induction motor where voltage permits, but on larger units always use a salient pole synchronous motor as being more efficient and able to give a big leading power factor.

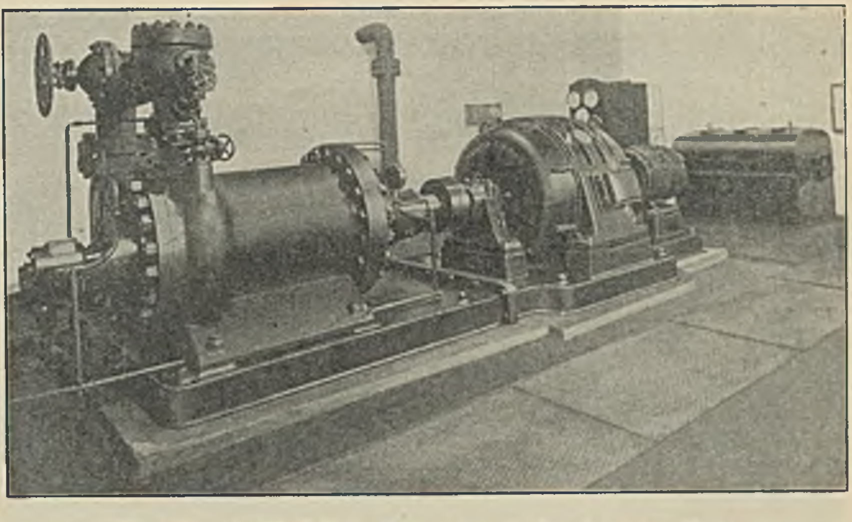

Fig. 11.—*A* 550 *B.H.P. Asynchronous Synchronous Motor driving Colliery Pump.*

Compensated Induction Motors.

Where heavy starting or running conditions make the use of asynchronous machines inadvisable, or for small outputs, say 10 H.P. to 150 H.P., the compensated induction motor is very attractive. It consists of an induction motor to which the power is led via the sliprings, the stator winding then forming the secondary winding and working at slip frequency. On the rotor there is another winding connected to a commutator the brushes bearing on this being connected through a starter to the secondary winding on the stator (see Figure 9).

As the second winding on the rotor is always exposed to a rotating magnetic flux at full line frequency, it develops a constant voltage irrespective of the speed. The voltage is transformed by the stationary brushes on the commutator into a voltage at slip frequency (i.e., the same as the secondary winding on the stator). Consequently, by connecting the brushes to the stator winding and suitably rocking the brushes, we can inject an exciting current into the stator secondary winding which will improve the power factor.

This motor is started up just like an induction motor, and has similar speed characteristic (see Figure 10). It has a greater overload capacity than an induction or a synchronous motor, very much so on a leading power factor and an equal or better starting torque than an induction motor. It is also well suited to run at very leading power factors.

At unity power factor a compensated machine and control gear may cost 50% more than an induction motor, but in terms of cost per wattless K.V.A. recovered, when working at 0.7 leading it will be equivalent to an induction motor plus 40/- downwards to less than 20/- per K.V.A. recovered, depending on the size.

As the power is fed into the sliprings it is of service for low voltage (below 1000 volts) only, but the field is very wide since it enables a unity or leading power factor machine to be installed on small drives and give practically the same mechanical performance as a slipring induction motor. It does not synchronise and so requires no extra exciter gear while the power factor can be varied by merely moving the brush rocker.

Figure 13 shews a 95 H.P. compensated induction motor driving a compressor.

Phase Advancers or Power Factor Compensators.

These can be of various types, but the two mostly in use are the oscillating type (Kapp Type) and the rotating type, and are applied to new or existing slipring induction motors above 250 B.H.P. The former has not found a very wide use, although it is quite effective. It consists of three armatures and commutators capable of independent rotation in a D.C. field. The brushes on the commutator are connected in star or delta and then through the main rotor starting resistance to the rotor sliprings. Its correcting effect, although giving a flatter power factor curve, tends to fall away at light loads, while the effect is also very dependent on the slip of the main motor.

A rather better result is obtained with a rotating phase advancer or compensator which is also more suitable for large motors. The compensator has an armature and commutator like a D.C. machine, the brushes being connected in the external rotor current of the main induction motor. It runs in a field with field coils, commutation poles and compensating windings. This machine when driven develops an E.M.F. which corrects the power factor of the main motor, by supplying the magnetising current at low frequency on the rotor circuit. By having wound shunt fields it enables a prac-

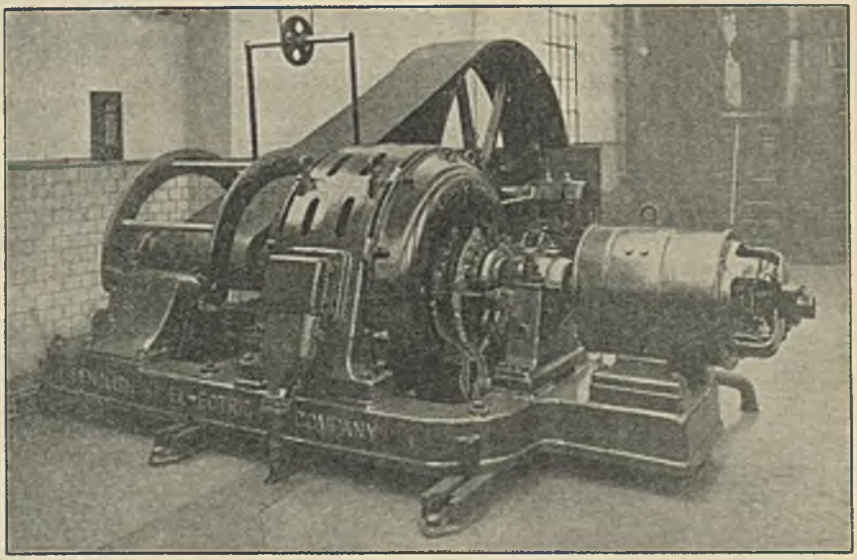

Fig. 12.—*A* 450 *B.H.P. Asynchronous Synchronous Motor driving Colliery Fan.*

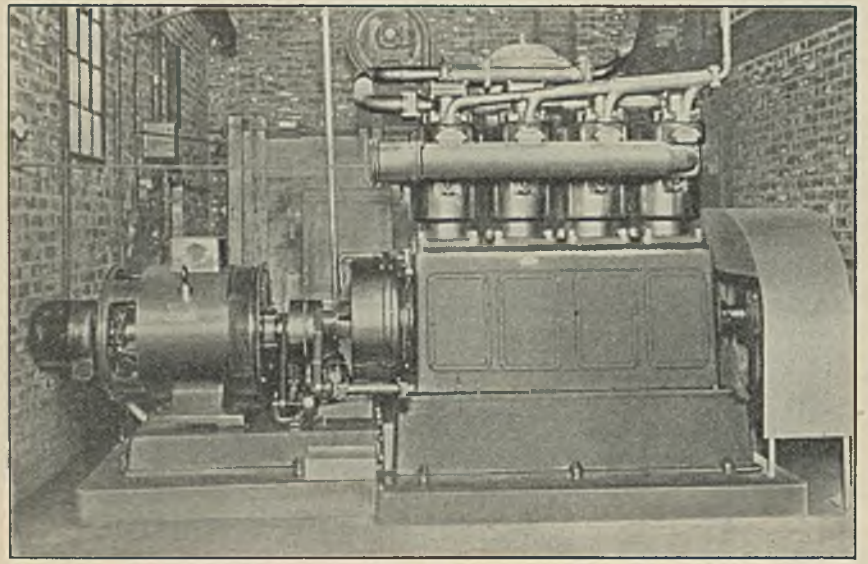

Fig. 13.—*A* 95 *H.P. Compensated Induction Motor driving a Compressor.*

tically constant power factor to be given over the load range and so is entirely automatic in this respect.

Both of these compensating devices are mainly suitable to operate very near to unity power factor, but can be applied to a motor of any voltage.

There is a similar type of rotating phase advancer or compensator used which has neither field coils, compensating windings, nor commutating poles. The rotor winding carrying the current provides its own field, and as this varies with the current, the compensating effect dies away at light loads.

The shunt type of rotating compensator has a performance as shewn in Figure 14. The diagram of external connections is shewn in Fig. 15. It will be noted that a motor driven compensator is shewn connected to the main motor stator direct or through a step-down transformer. This arrangement is very convenient and automatically provides the interlocking connections. The compensator itself forms the star point of the resistance starter which is of the open star or straight through pattern. This arrangement eliminates any switches without any disadvantages arising.

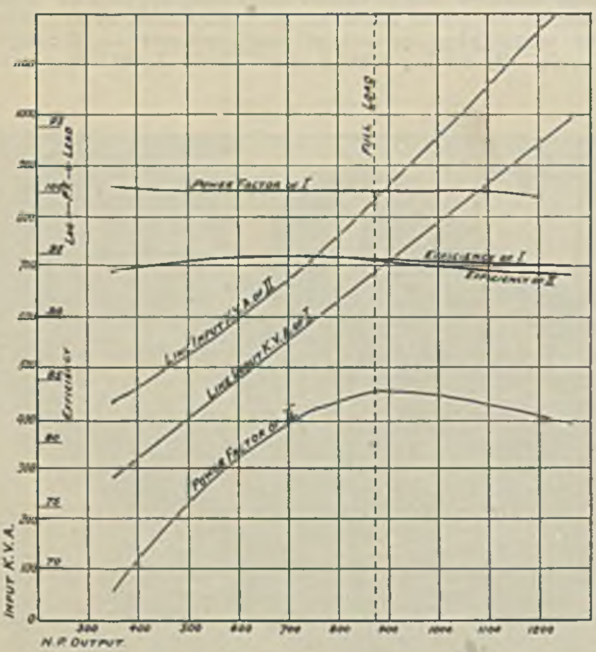

Fig. 14.—*I.* 875 *H.P.*, 250 *r.p.m.*, 50 *per.*, 440 *volt*, *S.R. Induction Motor and Compensator.*

II. ditto but plain S.R. Induction Motor.

The cost of a compensator in terms of wattless K.V.A. recovered is very low and may be from 20/- down to 10/-. When supplied with new slow speed motors, the extra cost over an ordinary induction motor may even be zero since the correcting effect may enable economies to be made in the design of the induction motor which will balance the cost of the compensator. Fig. 16 shows a motor driven compensator to give unity P.F. for a 2600 H.P., 166 r.p.m., induction motor.

SUMMARY OF CHOICE OF APPARATUS.

For locations where there is no rotating machinery, or where Squirrel Cage Motors only are admissible, use *Static* Condensers.

For small low voltage Motor Generator Sets, use Compensated Induction Motors and for large Motor Generator Sets use Salient-pole Synchronous Motors.

For more or less Constant Machine Drives where heavier starting duty is required, or where gradual resistance starting is desirable, and where a Leading Power Factor is necessary, use Asynchronous-Synchronous or Synchronous Induction Motors for large outputs and high voltages, but for low voltages and small outputs (up to 150/200 H.P.) use Compensated Induction Motors.

For drives where Heavy Torque Starting is required at unity power factor, which will dilute the wattless K.V.A., and therefore improve the power factor, use Induction Motors with added Compensators.

For drives involving Resistance Control, or where Constant Reversing is carried out, such as on cranes, it is not very practicable to correct the power factor on the machines involved, and it is better to keep to simple induction motors and obtain the correction elsewhere on more continuous running drives.

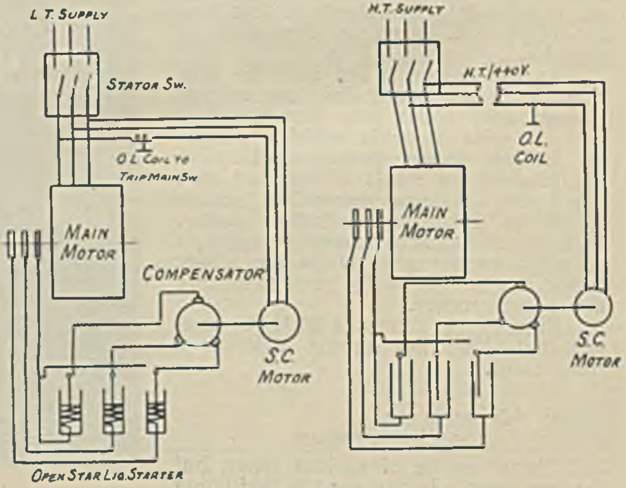

Fig. 15.

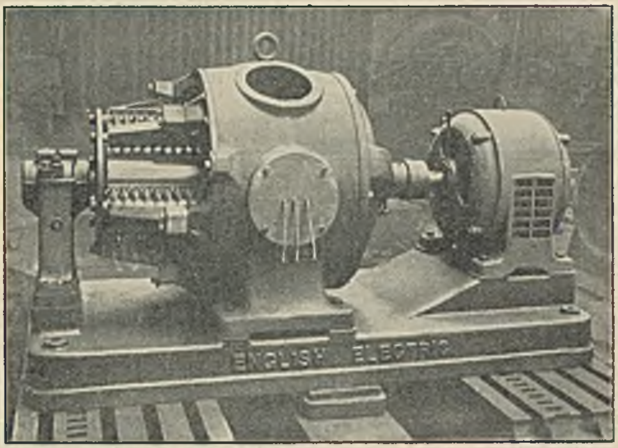

Fig. 16.—*Motor driving Compensator for a* 2,600 *B.H.P. Induction Motor.*

APPENDIX.

It has been suggested that, as this paper is written about the effects of a bad power factor, a non-technical definition of power factor will be useful for those who are out of touch with the question.

It should be clear that Power Factor is a ratio only of real power to apparent power equals

$$\frac{\text{Kilowatts}}{\text{Total Kilovoltamperes}} = \frac{\text{K.W.}}{\text{K.V.A.}}$$

In a direct current system all the current does work and so the real is the same as the apparent power.

In an alternating current system where the voltage pulsates 50 times a second, the useful current pulsates at the same time. In the case of a lamp circuit or a motor operating at unity power factor, this is the only current and so

$$\text{K.W.} = \text{K.V.A. or } \frac{\text{K.W.}}{\text{K.V.A.}} = 1 = \text{unity power factor.}$$

With induction motors, however, in addition to the useful current which does mechanical work, there is another current which pulsates out of time with the voltages.

It is analogous to a truck on rails where there is the useful pull in line with the rails and also a side or idle pull in addition (see Figure 17).

Now by mechanics we combine the forward and sideways pull into a total pull, as in diagram Figure 10.

This total pull is comparable to the total apparent power, K.V.A.; while the useful pull is comparable to the useful power, K.W.

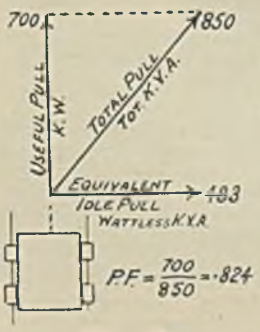

Fig. 17.

The idle pull is comparable to the idle or wattless K.V.A. which circulates but does no useful work.

As there is a right angle between the useful pull and the idle pull, any unknown can be calculated, since :

$$(\text{Total K.V.A.})^2 = \text{K.W.}^2 \text{ plus } (\text{Wattless K.V.A.})^2$$

$$\text{or as } \frac{\text{K.W.}}{\text{K.V.A.}} = \text{power factor}$$

$$\text{K.V.A.} = \frac{\text{K.W.}}{\text{power factor}}$$

A.M.E.E. Examinations, 1929.

REPORT OF THE CHIEF EXAMINER.

In the course of his Report on last year's examinations, the Chief Examiner, Prof. I. C. F. Statham, gives details and comments as follows:—

Certificate Examination.

Thirty candidates presented themselves for the Certificate Examination as compared with thirty-five in 1928 and thirty-six in 1927. The following is a summary of the results:—

First Class Certificates	5
Second Class Certificates	16
Fail	9

The successful candidates from the various branches were:—

Name.	*Branch.*	*Class.*
Fielder, W. P.	Yorkshire	First
Eames, H.	Do.	Second
Howe, R. H.	Do.	Second
Mann, J.	Do.	Second
Denholme, G.	East of Scotland	First
Hawksley, E.	Midland	First
Faust, F.	Do.	Second
Randall, H. W.	Do.	Second
Wyness, V.	Do.	Second
Wood, T. W.	London	Second
Burkle, B. J.	South Wales	First
Constable, C. E.	Do.	Second
Evans, A. C.	Do.	Second
Gay, W. T.	Do.	Second
Hilling, E. J.	Do.	Second
Robson, T.	North of England	First
Black, J.	Do.	Second
Fulton, H. A.	Do.	Second
Jeffrey, W.	Do.	Second
Rogers, E.	Do.	Second
Walton, J.	Do.	Second

An analysis of the entries and of the results obtained by candidates from the various branches is given in the following tabulated summary:—

Branch.	*Number of Candidates.*	*First Class Certificates.*	*Second Class Certificates.*	*Fail.*
Yorkshire	4	1	3	0
Scottish	3	1	0	2
Midland	8	1	3	4
London	1	0	1	0
S. Wales	5	1	4	0
N. England	9	1	5	3
	30	5	16	9

The standards obtained by the candidates in each of the papers were

Paper.	*Standard attained.* *First Class.*	*Second Class.*	*Fail.*
I.—Continuous Current	15	12	3
II.—Alternating Current	5	18	7
III.—Lighting and Signalling	5	21	4
IV.—Special Rules and Regulations	5	17	7*

* One Candidate did not take Paper IV.

From the above summary of the results it will be seen that few candidates displayed a First Class standard of knowledge except in Paper I.—Continuous Current.

The standard of the answers to Paper II. (Alternating Current) was not good, and only five candidates displayed a First Class knowledge of the subject. In view of the increasing, and almost universal, employment of Alternating Current for mining work, more attention should be devoted to this branch of the subject. No candidate can expect to obtain the Association's Certificate without a reasonable acquaintanceship with the theory and practice of A.C. This applies especially to the requirements for the First Class Certificate. The general standard of knowledge of Lighting and Signalling (Paper III.) and of the Regulations (Paper IV.) also leaves much to be desired. Many of the candidates appear to be insufficiently familiar with the official requirements repecting the use of electricity in mines and of the ordinary precautions adopted to guard against danger. Ignorance on these matters is inexcusable as the necessary information on the subjects is readily available, and should be in the possession of all Colliery Electricians worthy of being put in charge of electrical apparatus.

The Honours Examination.

Six candidates sat for the Honours Examination, the geographical distribution of the candidates according to their branches being

Yorkshire	1
London	1
South Wales	2
North of England	2

Only one candidate reached the standard required for a pass in this grade, viz.:—

Wiffen, J. W. .... North of England Branch.

The standard of electrical knowledge and general education of the Honours candidates was far from satisfactory. The possession of the Honours Certificate is an indication of competency to fill the position of Chief Electrician or Electrical Engineer to a group of collieries. Judging from the work submitted the majority of the candidates were considerably below that standard.

Association's Gold Medals.

No candidate reached a sufficiently high standard to receive the Association's Gold Medal: the highest marks obtained in the Ordinary and Honours Grades respectively being 77% and 70% of the totals.

In General.

The general standard of education of the candidates is not yet satisfactory. The improvement shown last year has not been maintained. The standards of spelling, grammar, and arithmetic, the arrangement of the work (particularly the mathematical answers) and the character of the sketches submitted, are lower than might be reasonably expected, in view of present facilities for general education.

Professor Statham, in concluding his closely critical report, says: "It is regrettable that out of the large number of persons engaged on the electrical side of colliery work, only thirty-six evince a desire to obtain a qualification which, while it may not be a guarantee of competency, does at least indicate that the holder possesses a sound knowledge of electricity applied to mining."

"The rapidly increasing application of electricity to mining operations, calls for more and more skilled and qualified men, and I am rather surprised that the recent focussing of attention upon the requisite qualifications of colliery officials has not led to an increase in the number of candidates for the only certificate bearing directly upon colliery electrical engineering. Improvement in the status of Colliery Electrical Engineers will only be brought about by increased technical qualification and the advantages of holding the Association's Certificate should be brought prominently before all engaged on the electrical staffs of collieries."

"An increase in the number of entrants to the Association should not, however, be sought by lowering the standard of the examinations which should be maintained at such a level that the possession of a Certificate is a guarantee that the holder has sufficient knowledge to enable him at all times to perform his duties in a safe and efficient manner."

NEW CATALOGUES.

ENGLISH ELECTRIC Co., Ltd., Queen's House, Kingsway, London, W.C. 2.—Publication No. K 43 is a useful description of Power Factor Compensators which not only gives general particulars of the machines but also technical data regarding their services and economies.

ELECTRIC CONSTRUCTION Co., Ltd., Wolverhampton.—B 626 is a high-class catalogue giving details, with many illustrations, of the E.C.C. rotary converters.

GENERAL ELECTRIC Co., Ltd., Magnet House, Kingsway, London, W.C. 2.—Leaflet S 5262 is a price sheet dealing with Bakelite detachable ceiling roses and suspension plates.

SIEMENS ELECTRIC LAMPS & SUPPLIES, Ltd. 38 and 39 Upper Thames Street, London, E.C. 4.—Particulars of the "Seelco" wiring system are given in the very complete illustrated price list, catalogue No. 428.

MAVOR & COULSON, Ltd., 47 Broad Street, Mile End, Glasgow, S.E.—Pamphlet 258/1 is a loose sheet for inclusion in the Company's main catalogue. It deals with flameproof controllers of the vertical air break type. Another interesting list gives an illustrated description of the new "M & C" troughed belt gate-end loader.

HEYES & Co., Ltd., Water-Heyes Electrical Works, Wigan.—The well-known "Wigan" signalling apparatus for mines is dealt with in the catalogue B.1. which gives full particulars of the systems and all apparatus connected therewith.

An interesting publication of Heyes & Co., is the "Wigan" Review, a "house organ" which is to be issued monthly and of which the first gives promise of an attractive and useful series.

BRITISH INSULATED CABLES Ltd., Prescot Lancs.—Three art illustrated folders describe respectively single phase meters, ebonite sheathed cables, and switch cut-outs.

A handsome catalogue gives interesting details and many illustrations of the Prescot works of the Company. The whole process of modern cable making is described very clearly.

J. A. CRABTREE & Co., Ltd., Lincoln Works, Walsall. —A handy pocket price list covers a complete range of switches, accessories and details.

ADAM HILGER Ltd., 24 Rochester Place, Camden Road, London, N.W. 1.—Spectrographic outfits for metallurgical analyses is the title of an interesting and very informative catalogue which gives many illustrations and complete prices for items of apparatus as well as for laboratory outfits.

WM. SANDERS & Co., Falcon Electrical Works, Wednesbury.—The illustrated price list of Sanders' Switchgear includes also flameproof switches and combined switches and fuses as well as other ironclad types.

Manufacturers' Specialities.

Portable Distribution in Mines.

Electrical distribution in coal mines has always been a very difficult problem for the mining electrical engineer. This, no doubt, is largely due to the need for an ever-changing network, brought about by the complexity and the advance of working, met with in the average mine. With permanently fixed switchgear, the electrician has to decide the most advantageous situations of installation to give maximum distribution service to the many coal faces; that is by no means a simple task when one considers the rapidly changing conditions as new districts are opened out in various directions and older workings are abandoned.

Portable electrical apparatus has long been recognised as the most satisfactory solution of the problem, but it has always been more or less restricted in its usefulness of application because of the necessity of sealing the cables, to comply with the Coal Mines Act. To cope with this difficulty Messrs. A. Reyrolle & Co. Ltd. have recently developed a very useful plug link box, which can be adapted to any of their portable mining switchgear.

Some idea as to the variety of uses to which this box may be put will be gained by reference to Figs. 1 and 2. Fig. 1 shows a gate-end switch mounted in a recess in the haulage road way and fitted with detachable cable dividing boxes. In this case the tee-off trailer cable to the gate-way is connected through a gland to terminals enclosed in a special flame-proof terminal box; but, alternatively, similar units fitted with interlocked plugs and sockets are manufactured. After the gate-way has been worked out, the plug boxes can be detached from the switch unit, and the two boxes plugged into each other, as shown in Fig. 2, so forming a plug link box and an effective cable connection without the necessity of cable re-jointing and its attendant difficulties. The switchgear may then be moved further in-bye for the opening out of another gate-way.

Again, in long-wall working, a simple means of extending the cable to follow up the coal face as it advances is provided: and a diversity of other uses to which this handy apparatus may be put will suggest themselves to the colliery electrician.

The casing of each box is of heavy cast iron and a mechanical grip gland is fitted. Provision is made for sealing the cable, the tails of which are connected to the terminals of socket contacts, these being embedded in a moulded bakelite insulator. Electrical contact between two boxes, or between one box and the busbars of the switchgear, is made through loose plug-links which plug into the socket contacts. The mechanical joints is made on a wide machined flange, and locating pins are provided to ensure correct alignment of the contacts.

This apparatus complies in detail with the Home Office requirements for the use of electricity in mines. and is proving itself a boon to engineers faced with underground distribution difficulties.

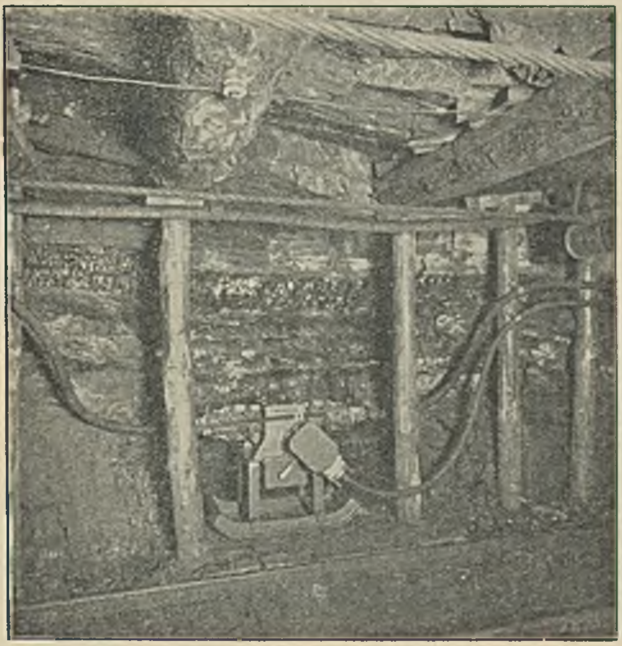

Fig. 1.—A 60-amp. portable Gate-end Switch fitted with detachable dividing boxes and mounted in a recess in the main haulage road-way.

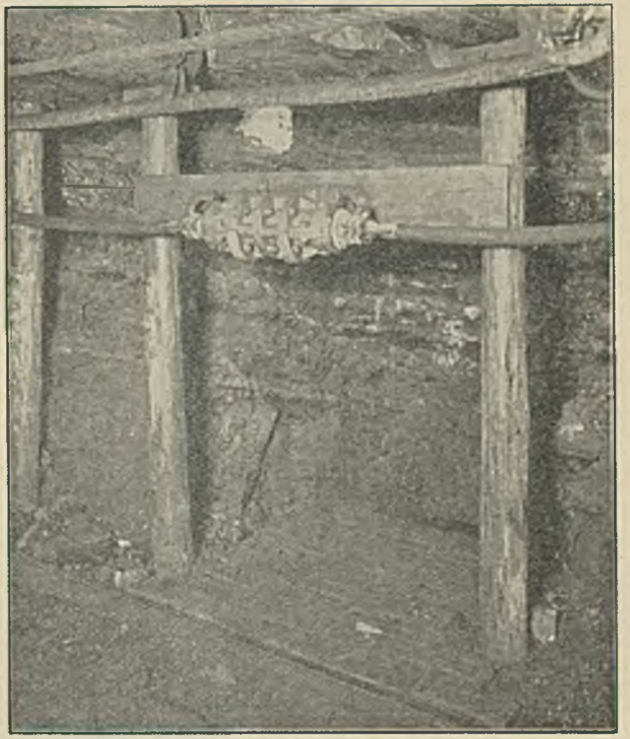

Fig. 2.—The same situation (as in Fig. 1) at a later date, after the switchgear had been removed to follow up new workings. Note the cable joint made by utilising the detachable dividing boxes.

Reyrolle at Cardiff Exhibition.

Messrs. A. Reyrolle & Co., Ltd., put together an exceptionally attractive display at the recent Cardiff Engineering Exhibition which comprised a representative range of their smaller products, including the wellknown air-break switches, fuse-boxes, and plugs, which are arranged for unit construction. An attractive display board of domestic plugs and sockets of various sizes and patterns for use with portable apparatus was also shown. These plugs and sockets are manufactured to British Standard Specification No. 196-1927, and, being of metal-clad construction, with provision for an earth connection, render any apparatus to which they are fitted perfectly safe to handle. The makers claim that the smaller sizes of these plugs can be used in place of switches to make and break current up to their full rated capacity; the continuously safe breaking capacity of the plugs was effectively demonstrated by means of a simple testing apparatus.

An exhibit of special interest to Supply Authorities and engineers who have experienced difficulty in economically tapping extra-high-tension lines for supplies to small consumers was the ring-main isolating switch recently developed by this firm. The unit comprises two oil-immersed isolating switches to enable it to be connected in, or isolated from, the main supply line, and a tee-off circuit through an oil-immersed switch fuse is also provided. The apparatus is of weatherproof and flood-proof construction, and simple but definite interlocks are provided to prevent a wrong sequence of operation.

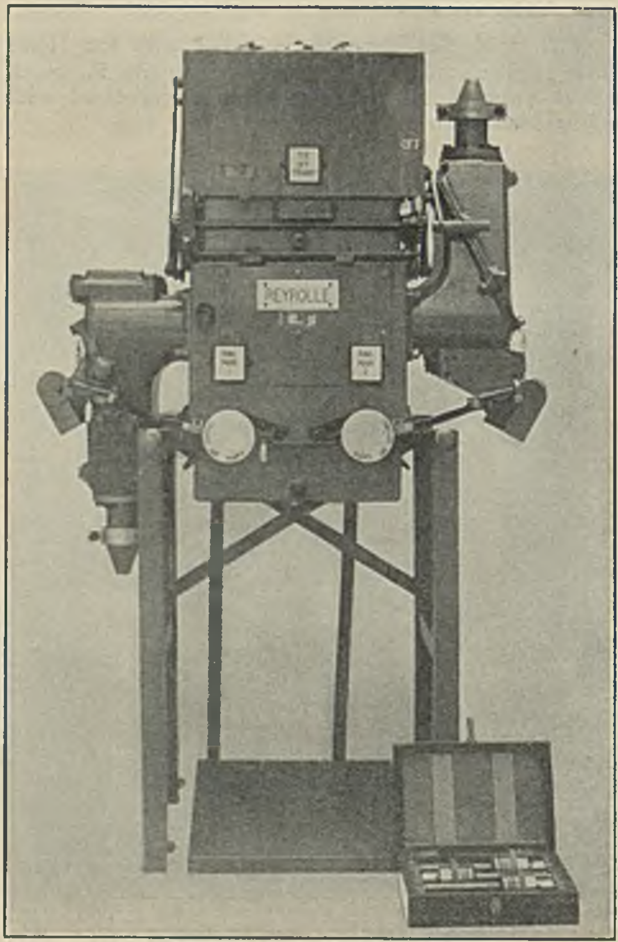

Fig. 1.—Ring-main Isolating Switch for 200-amp. Main and 100-amp. Tee Branch.

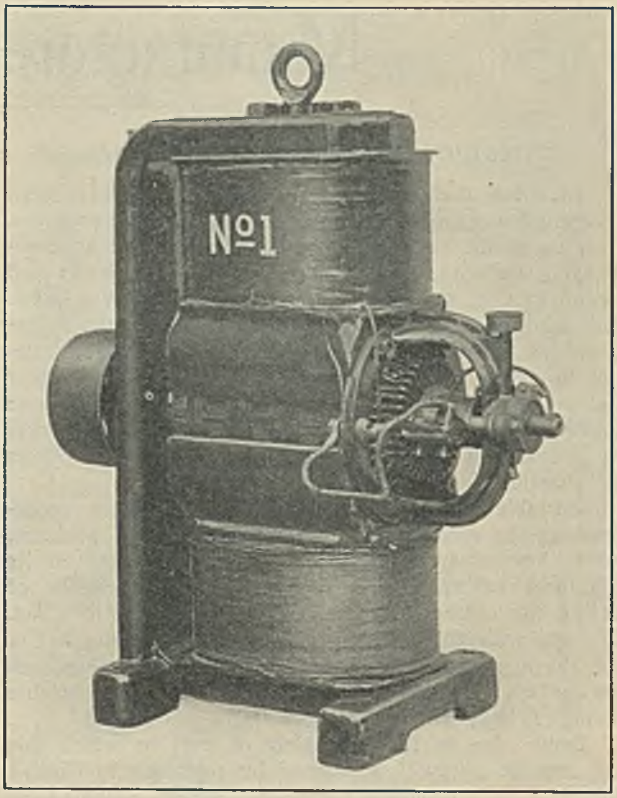

Fig. 2.—The First "Holmes" Dynamo (built in 1885).

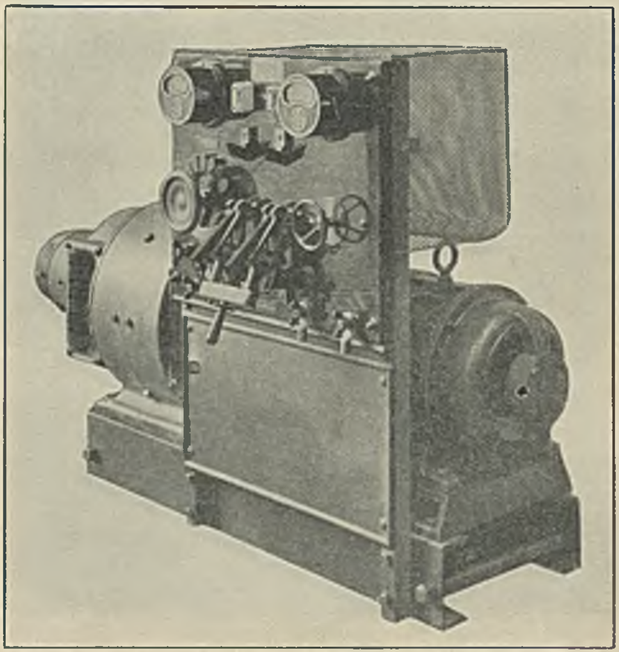

Fig. 3.—Holmes Arc-welding Equipment.

Messrs. Reyrolle also exhibited on behalf of Messrs. J. H. Holmes & Co., Ltd., an associate firm, a set of automatic street traffic control signalling apparatus of the type now becoming a familiar sight in the busiest thoroughfares. The apparatus complies in detail with the latest recommendations of the Ministry of Transport, and the design is claimed to be superior in certain details to many of the foreign installations which have been imported into this country. Messrs. Holmes also exhibited an up-to-date electric arc-welding equipment, and there was an exhibit of unique historical interest, namely, the first dynamo manufactured by Messrs. J. H. Holmes and Co. over 40 years ago, and which, until quite recently, was still in commission and giving satisfactory service. This sturdy old veteran was released from duty only at the special request of Messrs. Holmes, in order that it might be preserved as an original relic of their early work.

S. & C. Internal Isolation Switchgear.

Last year, at the Cardiff Engineering Exhibition, Switchgear and Cowans Ltd. showed the first switchgear unit built by them, embodying in a practical manner the new Whitehead principle of isolation. That unit cubicle aroused considerable interest and therefore the exhibits shown in Cardiff this year were particularly notable, for they included two sizes of metalclad switchgear units all built on the Internal Isolation Principle and embodying the patented circuit breaker isolating carriage. Comparison of these units with the cubicle shown last year emphasised the great advance that has been made in developing and applying the principle of "isolation without moving the mass" while at the same time incorporating the most modern practice in the design and construction of metalclad switchgear.

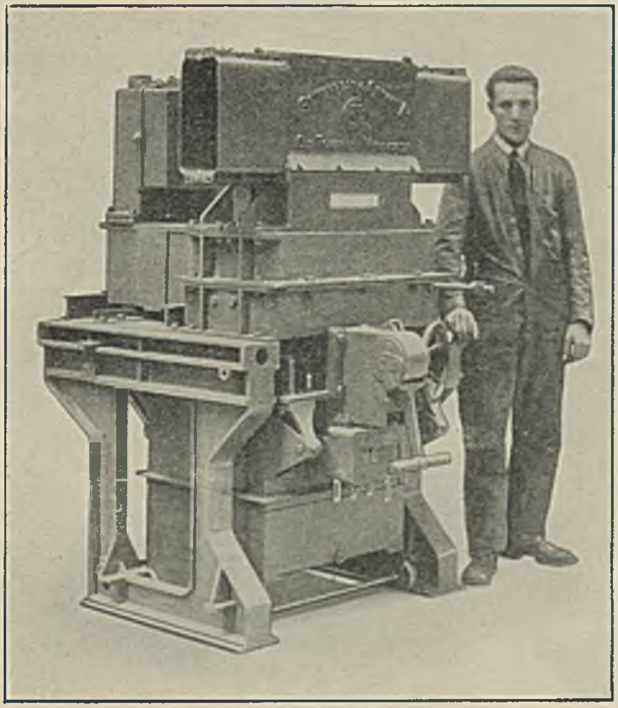

Fig. 1.

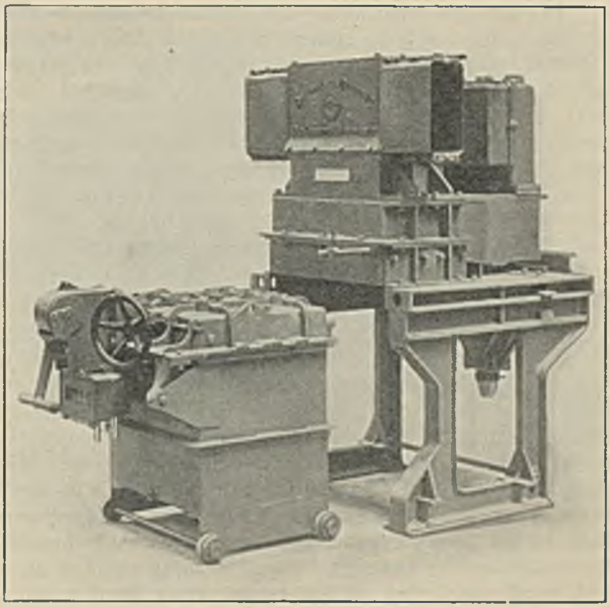

Fig. 2.

The evolution of Internal Isolation Switchgear is a story that excites the imagination. Years of effort by switchgear designers to produce practical switchgear, but hidebound to the conventional practice of moving the complete circuit breaker when isolating from or connecting to the line, a great complication to disconnect or connect six simple plugs and sockets. Then the inspiration of the Whitehead principle of isolation and, advancing through designs, tests, modifications, and again modifications, Switchgear & Cowans Ltd. produce, in the short period of two years, the simple Internal Isolation Switchgear in which isolation is safely and conveniently effected without moving the circuit breaker.

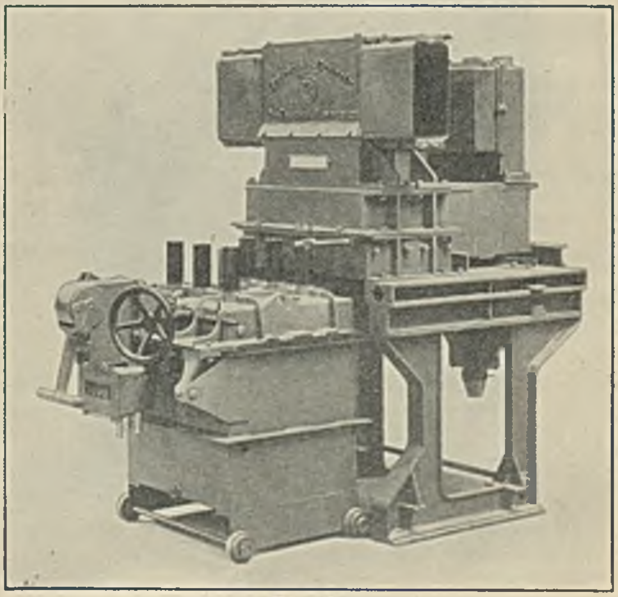

Fig. 3.

In the new switchgear the circuit breaker remains in the same position, stationary on the floor, whether connected to or isolated from the line. As the breaker is not moved horizontally nor raised or lowered vertically, all the heavy gear and framework for these purposes are eliminated. Figure 1, illustrating a complete unit of 250,000 K.V.A. rupturing capacity, shows the great reduction in size and weight which has been effected. All components are metalclad self-contained units, easily removed and inspected. When it is necessary to inspect the breaker contacts, the breaker is pulled out on its wheels along the floor as shown in Figure 2.

The vital component of Internal Isolation Switchgear is the moving Isolating Carriage, which is arranged to move up and down within the breaker tank. The six terminal stems of the breaker instead of being, as is the usual practice, fixed to the breaker top plate are mounted in insulating shrouds fixed to the isolating carriage. The terminal stems are thus employed in a dual capacity, their lower ends forming the circuit breaker fixed contacts in the usual manner, and their upper ends forming the isolating plug contacts. These six plug contacts make and break connection with a group of six fixed terminal sockets. Three of these socket contacts are connected to the three busbars. Each of the other three socket contacts is connected through a bridge connector (or a current transformer) to the incoming cable. When isolating from the line the breaker remains stationary; the only part that is moved is the isolating carriage with its plug contacts. Simply to raise or lower the isolating carriage inside the breaker tank by means of a handwheel outside, connects the breaker to or isolates it from the line. When the isolating carriage is raised to connect the breaker to the line, the plug contacts project through the breaker top plate and make connection with the fixed socket contacts. When in this position, the breaker can be operated, closed, and tripped, just as if the terminal stems were permanently fixed to the top plate of the breaker.

It is obvious that the switchgear is self-interlocking. The sequence of operations is inherent and simple, no intricate system of complicated interlocks being necessary. When connected to the line, the breaker cannot be pulled out against the natural interlocks of the plug contacts extending up into the fixed socket contacts. When the breaker contacts are closed, they prevent the isolating carriage from being moved down; the breaker must first be tripped. The main current cannot be made or broken at the isolating contacts, but only at the breaker contacts, under oil. When withdrawn, the breaker cannot be pushed home into position with the contacts closed, as the plug contacts are then projecting above the top plate. To take any strain off the gear, these natural interlocks are supplemented by two simple interlocking bolts.

Figures 2 and 3 show the circuit breaker withdrawn for examination. In Figure 3 the isolating carriage has been raised to its top position so that the isolating plug contacts are projecting through the top plate. The breaker can only be inserted with the isolating contacts

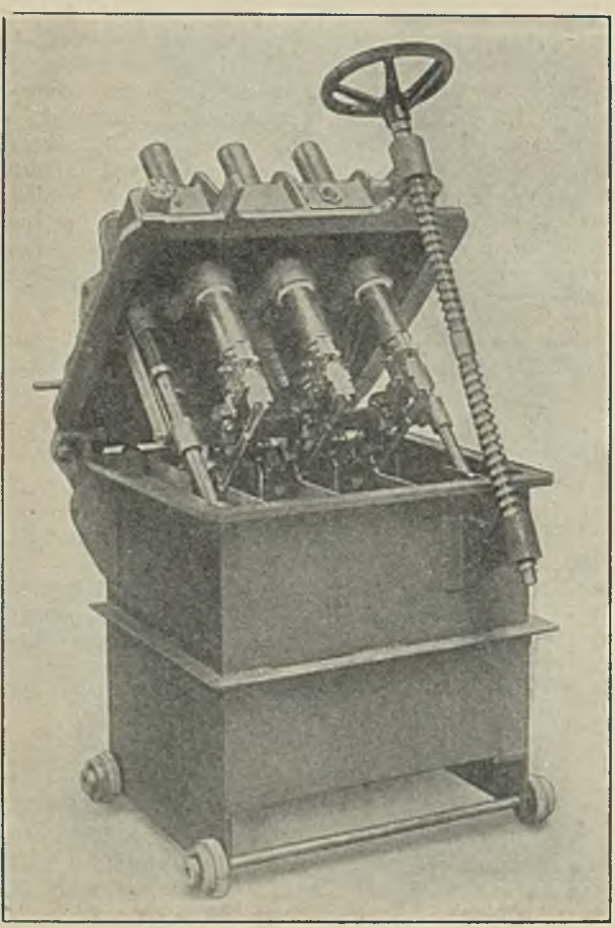

Fig. 4.

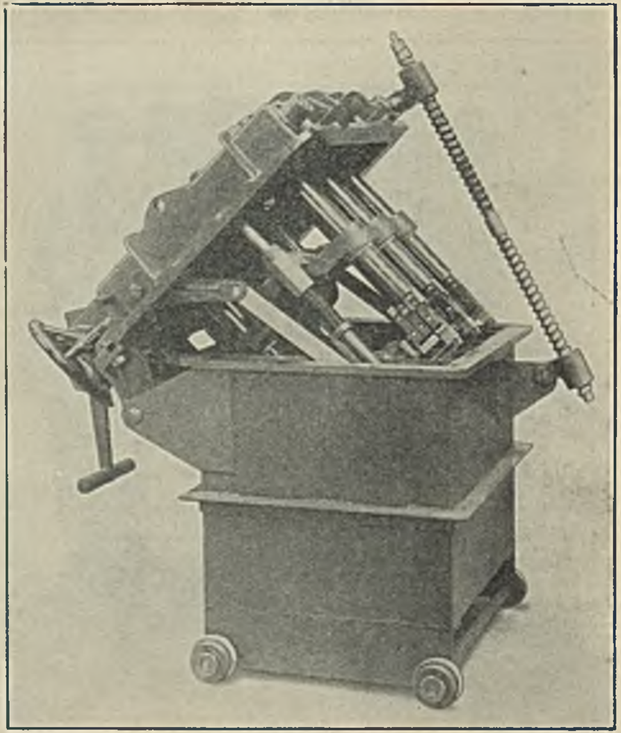

Fig. 5.

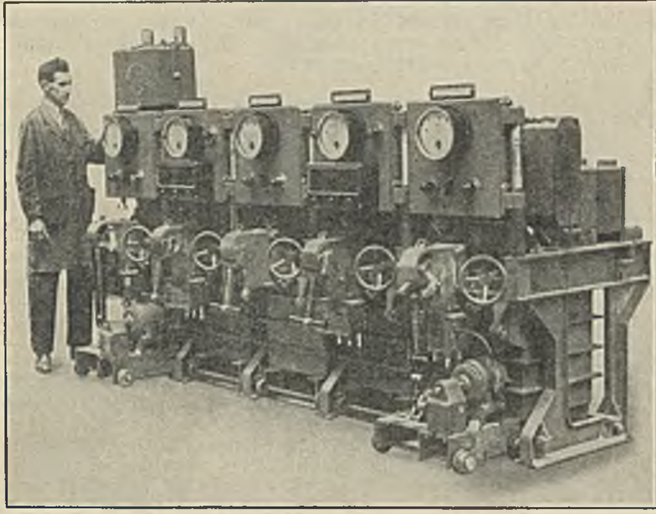

Fig. 6.

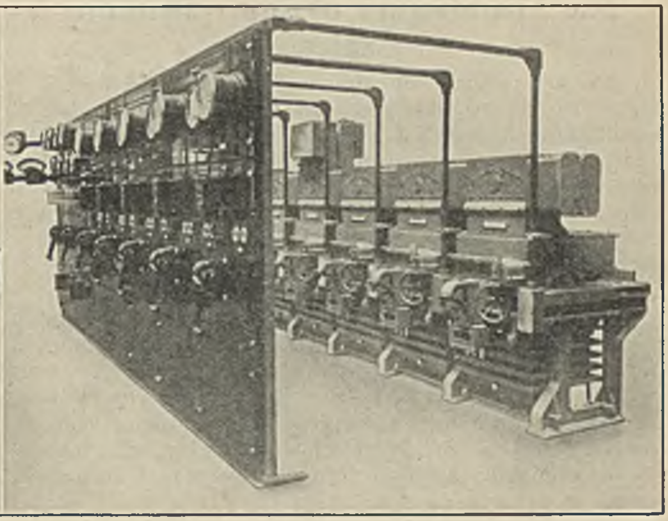

Fig. 7.

lowered, and then, to connect the breaker to the line, the isolating contacts are raised into the position shown.

When duplicate busbars are required, busbar selection is efficiently obtained by utilising the circuit breaker as a selector switch. The only addition required is a duplicate set of three fixed socket contacts connected to the cable box terminals, while the circuit breaker is arranged to occupy two positions, each set of three busbars having, of course, its own set of three socket contacts. By this means it is possible promptly to change over from one set of busbars to the other by simply moving the circuit breaker on its wheels backwards or forwards a few inches, the plug contacts on the isolating carriage connecting one or other set of three cable socket contacts to one or other set of three busbar socket contacts.

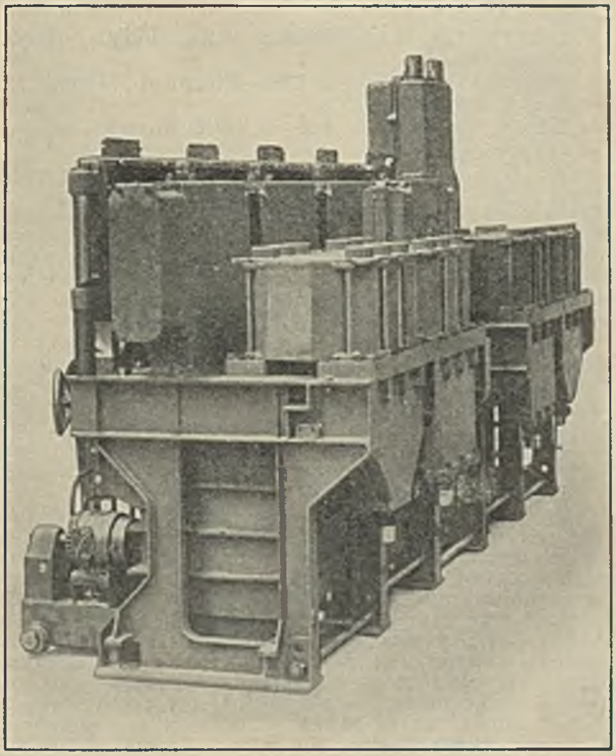

Fig. 8.

In view of the fact that the isolating carriage is incorporated in its design, the circuit breaker is of special interest, particularly so because of the ingenuity with which this has been accomplished. The top plate of the breaker is hinged, and lugs are provided on the top plate and on the tank for attaching a simple screw jack: after removing the bolts in the top plate, a few turns of the handwheel on the jack, Figure 4, swings back the top plate and the breaker contacts are fully exposed for examination. The complete operation of isolating, withdrawing and opening the circuit breaker takes but a few minutes and is done in perfect safety. In Figure 5 the isolating carriage has been lowered to show how it carries the terminal stems fixed in bakelite shrouds. When the top plate is opened up, the circuit breaker can be opened and closed, facilitating adjustment of the moving and fixed contacts.

The illustrations, Figures 6 and 7, are of two types of switchboards formed of Internal Isolation Switchgear Units, as installed in a sub-station on the "Grid." The board shown in Figure 6 has two incoming panels and five feeder panels. The mechanical operating rods from the control panels to the circuit breakers are not shown. The five panel board, Figure 7, is for a London sub-station; it has two incoming panels, two feeder panels with motor operated circuit breakers, and one busbar coupler panel.

How each switchgear unit is built up of metalclad, interchangeable, self-contained components, is shown in Figure 8, which is a back view of a switchboard, showing the arrangement of the potential transformer, current transformers or bridge connectors, and cable boxes; each metalclad component is easily accessible and can be removed and replaced individually.

The Manufacture of Super-Tension Cables.

By the courtesy of Messrs. W. T. Glover & Co. Ltd., we were recently previleged to view the complete manufacture of their super-tension cables. A remarkable advance on older methods was evident. The practical application of the essential principles, viz.:—total elimination of moisture, perfect impregnation and the application of the dielectric to the conductor out of contact with the air was a striking testimony to the ingenuity and courage of the engineers of the Company.

We are now able to supplement with greater detail the general particulars given in our issue of October last.

The paper as received from the mill in wide rolls is drawn in sheet form through a heated chamber under vacuum, on through a bath of hot impregnating compound still under vacuum, through squeezing rolls into a tank of hot compound at air pressure, and finally into the atmosphere where it is wound on to a divided mandrel. During the final stages of this process it receives a surfacing layer of compound to provide the necessary lubrication between the layers and to ensure flexibility of the cable. The roll of impregnated and surfaced paper is then cut in a lathe into flat spools of ribbon on the separate centres of the divided mandrel.

These spools of paper are applied to the conductor by an entirely new design of machine in which the conductor is made to revolve, at the same time travelling forward and drawing the ribbons of paper on to itself with a precision hitherto unattainable by the older methods.

The great advantages of this form of machine are that the brackets carrying the paper spools do not revolve and can thus be accurately adjusted during working, and also the whole of the cable and the on-going papers can be completely submerged under the surface of hot compound.

The occlusion of air and moisture is thus impossible; and the layering of the paper ribbons is perfected in regard to pitch, overlap and pressure, because the fixed spools can be adjusted to feed exactly at the angle and tension required.

In addition, the precision of this method ensures that the films of free compound are uniformly enclosed between the paper layers and the solidifying points of the compounds used are higher than the maximum working temperature of the cable so that drainage under any condition is impossible.

"Sousedik" A.C. Motors.

A new Company is in course of formation for the manufacture in this country of "Sousedik" Automatic Starter Motors and "Sousedik" Variable Speed A.C. Commutator Motors, and it is confidently expected to commence production in the very near future. These motors, and the claims in their favour, have been investigated by consulting engineers and by well-known industrial engineers. The general opinion is that the inventor has achieved, in a simple and direct manner, important improvements which have been sought ever since A.C. Current was first used. Technical details will be published in an early issue of this journal. In the meantime, pending the completion of the new Company, enquiries will be handled by Mr. Thomas T. D. Geesin, 138 Glasgow Road, Paisley. Mr. Geesin is able to guarantee the prompt dispatch of Continental made motors to meet urgent demands.

British Trade Exhibition in South America.

This exhibition is to be held in Buenos Aires during 1931. An advance copy of a pamphlet gives a good deal of information with regard to the exhibition which has not hitherto been published. This subject is of special interest at the present moment, in view of the work accomplished by the D'Abernon mission and of the strong desire shown in official and other circles to press on with vigour the campaign to recover Britain's trade supremacy in South America. A list of the Grand Council of the exhibition has also been issued. The date is now definitely fixed as from February 18th to April 2nd, 1931. The pamphlet is worthy of careful study by British manufacturers. It can be obtained from Mr. W. S. Barclay (general secretary of the exhibition). 5 Parliament Mansions, Orchard Street, London, S.W. 1. The exhibition has been organised by the British Chamber of Commerce in the Argentine Republic (Incorporated), and Sir Henry Gibson, K.B.E., is chairman.

The Cardiff Exhibition.

This exhibition, which concluded on the 7th inst., was one of the most successful of the annual series instituted in 1922. The articles on pages 227-231 deal at some length with a few of the more prominent exhibits showing originality. Space prevents any more than brief mention of other notable displays amongst which were:—

Thor Lamps and Supplies Ltd.; Wolf Safety Lamp Co., Ltd.; Ceag Ltd.; Oldham & Son, Ltd.—Miners' Electric Lamps.

Gent & Co., Ltd.—Mining Bells, Signals, Relays, Telephones, &c.

Evershed & Vignoles, Ltd.—Electrical Testing and Measuring Instruments.

Edison Swan Cables, Ltd.—Electric Mining and other Cables and Wires.

W. B. Dick & Co., Ltd.—The merits of the well-known "Ilo" lubricating oils and greases, and particularly those for colliery, steel and tinplate works' purposes, were attractively demonstrated. This Company realises the value of technical and research work; having its own laboratories, as well as interests in the U.S.A. oilfields, oils for turbines, transformers, and other electrical services are leading "Ilo" specialities.

George Ellison, Ltd.—This Company's exhibit included a demonstration van equipped with examples of flameproof low-tension A.C. or D.C. apparatus, a gate-end circuit-breaker equipment; also oil-immersed circuit-breakers, a low-tension draw-out unit, together with small-sized oil-immersed straight-on and star-delta starters. Another interesting item shown was a range of "Tufnol" insulating materials.

Brookhirst Switchgear, Ltd.—Direct-current control gear. Midget faceplate type, hand-operated, for the control of motors up to 10 H.P. Drum type, hand-operated, for the control of motors up to 100 H.P. Junior solenoid type, automatically operated for motors up to 12 H.P. Solenoid type, sutomatically operated, for motors up to 35 H.P. Alternating-current control gear: Oil-immersed star-delta starter, hand-operated, for the control of squirrel-cage motors up to 50 H.P Air-break rotor and stator control pillar, hand-operated, for the control of slipring motors up to 60 H.P. Contactor type automatic rotor and stator control pillar for slipring motors up to 100 H.P.