The Mining Electrical Engineer.

OFFICIAL JOURNAL OF THE ASSOCIATION
OF MINING ELECTRICAL ENGINEERS.
EDITED BY E. DINSDALE PHILLIPS.

Vol. IX. JUNE, 1929. No. 105.

An Asset to the Nation.

Whilst the publication of this issue marks the completion of our ninth volume and the passing of the Association of Mining Electrical Engineers into a new "Session," it is particularly interesting to note that this year the A.M.E.E. attains its majority. Those who have been connected with the Association from the beginning, and there are quite a number who are still active members, must feel a high degree of personal satisfaction in reviewing the twenty-one years' work. Though a history of the A.M.E.E. would provide fascinating reading, those in the mining electrical business know that modern progress in this branch of engineering is so rapid and far-reaching that there is little time to dally with records of the past. Their time and these pages are always insufficient to meet the demands of the moment.

How extremely widespread have become the technical and economic interests of the mining electrical man is to some extent reflected in the nature of the papers submitted by members of the A.M.E.E. It has, in fact, become so difficult as to be well nigh impossible to suggest any one or two specific branches of colliery electrical work upon which future papers might be prepared and the deliberations of members engaged. To sell coal is the first and last aim of everyone engaged in mining; for the engineer this resolves itself into problems of getting coal cheaply and getting the greatest market value out of the least quantity.

The mining electrical engineer is the "power engineer" of to-day. A full knowledge of mechanical and electrical applications; the carbonisation of coal and the extraction of concentrated useful elements therefrom; the breaking up, cleaning, crushing and grading of coal for fuel or chemical or combined processes; the generation of electricity at large-power centres; the purchase and sale of electricity in bulk; transmission, transforming and distribution of extra high tension and medium pressure supplies—such are a few of the principal concerns of the mining electrical engineer broadly indicated.

One does not need any superacute vision to perceive the direction into which the career of the mining electrical engineer is rapidly advancing: and it is equally plain and evident that the work of the A.M.E.E. has barely begun. For it is essentially an educational institution, applying the lessons of natural science and bringing them into practical expression in commercial and industrial terms. The which, after all, is the true aim of all genuine scientific endeavour. It is the principle which inevitably will enter more fully for many years to come into the great national mining and electrical interests than into any other of our industrial spheres.

Whilst the A.M.E.E. continues to observe as a basic article of its creed the bringing together of men who are connected with every phase of electrical practice in regard to mining—be they consultants or coal hewers, professors or pumpmen, managers or mechanics—its value to the country is assured. The A.M.E.E. is an asset to the Nation. The index of our national prosperity would appear to be definitely set at "mining-electricity." In their way the members of the A.M.E.E. have a great opportunity before them; and in their progress making towards national betterment they cannot fail to gather as an incidental effect the enhanced individual reputation and status which are their due.

Convention Anticipations.

Sympathy and congratulations are alike due to the indefatigable people who are handling the business of organising the A.M.E.E. Convention at the Newcastle end. The expression of these very mixed sentiments is prompted by the latest report from that quarter—where the ever-willing harassed secretary is so over-worked that he would fain cry for quarter, whilst in the same breath (not being yet quite breathless), he excusably exults in the excellent response accorded to his efforts. From the highly satisfactory particulars given it would appear that there will be an attendance of about two hundred on the Tuesday at the informal Re-union and Presidential Reception which will mark the opening of one of the most interesting round of events and entertainments yet devised for the A.M.E.E. Annual Meeting. By the time the climax is reached with the annual general meeting, dinner and dance on the Friday, there will in all probability be some three hundred members and friends taking part.

As to the official visits—to the Derwenthaugh works of the Consett Iron Company, the Reyrolle electrical works, the Dunston Power Station of "carbonisation" up to date, the all-electric Seghill Colliery—already the lists show from 150 to 180 names of definite acceptances for each. Furthermore, and as a matter of course, the numbers of those who have spoken for places at the delectable luncheons and dinners, the dances and receptions, are no ways less than are the figures of the technical enthusiasts who would even volunteer to spend an open summer's day in exploring the confines of coking plants and switchgear factories. It is also, perhaps, unnecessary to mention that the Exhibition will prove irresistible to everyone attending the Convention.

So it is that, thus briefly, we would at this eleventh hour bring moisture to the anticipatory lips of the fortunate folk who have definitely decided to join in the festivities and, perchance, we might find that we have incidentally prevailed upon some of the halting and hesitant to take the plunge, impose a little more demand on the over-loaded secretary, and plead to be admitted, late-comers though they be.

NEW BOOKS.

H.M. STATIONERY OFFICE.

The following, printed and published by His Majesty's Stationery Office, can be purchased through any bookseller or directly from H.M. Stationery Office at the following addresses: Adastral House, Kingsway, London, W.C. 1; York Street, Manchester; 1 St. Andrew's Crescent, Cardiff; 120 George Street, Edinburgh; or 15 Donegall Square, W., Belfast.

Mines Department.—REGULATIONS AND ORDERS RELATING TO MINES under the Coal Mines Act, 1911: including Orders up to 1st January, 1929. Price 1s. nett.

After the Main Code of General Regulations, the remaining regulations and orders have been grouped under subjects, while in the Appendices are printed various memoranda and reference lists issued by the Mines Department. To facilitate reference, all Orders are printed to read continuously in the form in which they have effect and a general index (under general subject headings for the different classes of persons employed) is included at the end.

Included among the several appendices are the following: Memoranda on the Storage of Explosives, the Test of Explosives, the Test of Safety Lamps, and the Test of Rescue Apparatus. Rescue Work, List of Approved Breathing Apparatus; First Aid Certificates, List of Approved Societies; Managers' and Under-Managers' Certificates, List of Approved Institutions; Surveyors' Certificates, List of Approved Institutions; Firemen's, etc., and Shotfirers' Certificates, List of Approved Schools, Institutions and Authorities, and Scale of Fees.

Mines Department.—OUTPUT AND EMPLOYMENT AT METALLIFEROUS MINES, QUARRIES, etc., during the Quarter ended 31st December, 1928. Price 4d. nett.

A series of Tables indicating: Output and Employment at Iron Ore and Ironstone Mines and Quarries; Output at Mines, Quarries, etc., producing Non-Ferrous Metalliferous Ores and certain other Minerals; Number of Persons employed at Mines, Quarries, etc. producing Metalliferous Ores and certain other Minerals; Average Selling Prices of certain metals.

THE A.T.M. TELEGRAPH ENGINEERS' HANDBOOK. The Automatic Telephone Manufacturing Co., Ltd., Strowger Works, Liverpool. Price 2s. 6d.

This is a technical book for the easy reference of telegraph engineers when problems arise in daily practice. The several sections include: Overhead Telegraph Transmission; Leaky Lines; Transients; A.T.M. Gulstad Relay; Relay Testing Sets; Universal Duplex Unit; Vyle Polarised Sounder; also a Table of Exponential and Hyperbolic Functions, and a descriptive appendix illustrating A.T.M. Telegraph Apparatus.

THE PRINCIPLES OF SUBSIDENCE AND THE LAW OF SUPPORT in Relation to Colliery Undertakings: W. T. Lane, F.G.S., M.Inst.M.E., M.I.M.S. and J. H. Roberts, B.Sc., M.I.M.S. 320 pp., 71 diagrams. London: Alfred A. Knopf, Ltd., 37 Bedford Square. Price 18s. nett.

In the "Introduction" Prof. George Knox, F.G.S., M.I.M.E., indicates the extremely important nature of the contents and the original and valuable method which the authors have adopted.

A sound knowledge of the principles of Mining Subsidence and the application of the Law of Support is of extreme importance to all those who are in any way connected with mining undertakings; moreover, the subject is one which concerns more or less directly estate agents and surveyors, landowners and builders, as well as railway, gas, water and municipal engineers. To the legal profession the contents of the book are, of course, of paramount importance.

This volume, which besides being both concise and readable has been compiled by leading experts on the subject, undoubtedly fills a gap in existing technical literature. Not only does it treat authoritatively of past observations, records, and theories formulated, but it further crystalises these into the form of a logical and connected text-book, which will prove of the greatest possible service to students of the subjects dealt with therein.

BRITISH ENGINEERING STANDARDS.

Copies of the Specifications herein referred to can be obtained from the Publications Department, British Engineering Standards Association, 28 Victoria Street, London, S.W. 1.

Brass Armouring Wire for Electric Cables.

The wire dealt with in this specification is intended primarily for use in the automobile and similar industries. The specification provides for three sizes of wire, and specifies the chemical composition of the material, the tolerances permitted on the dimensions, and the finish of the wire: mechanical tests are included, and the procedure of selecting samples for these tests is laid down. Specification No. 356-1929. Price 2s. 2d. post free.

Electricity Meters and Ceiling Roses.

These are the subjects, respectively, of Specifications Nos. 37-1929 and 67-1929. They are revisions of previous issues. Price each, 2s. 2d. post free.

CORRECTION.

Ball and Roller Bearings.—On page 363 in the May issue, in the Reply of Mr. James Anderson, a sentence reads: "If a bearing be run under a particular load for 100 hours failure will ensue in about 93% of cases." The latter phrase should read "in about 10% of cases."

Failure of a Motor to Start.

F. MAWSON.

(This is the fourth of a series of Articles intended more particularly to help Students and Junior Engineers).

(Continued from page 360*).*

CONTINUOUS CURRENT MOTORS.

If a motor fails to start when connected to the supply mains in the usual way, the failure may be due to:

1. Failure of the supply.
2. An open circuit.
3. A short circuit.
4. A wrong connection.

Occasionally the trouble may be purely mechanical.

An Open Circuit.

If the failure is due to an open circuit or to failure of the supply, there will be no flash when the starting switch is moved to the first contact and off again. A test with either a lamp or voltmeter will be sufficient to ascertain whether or not the mains are alive.

An open circuit fault may be traced to any of the following causes: (a) fuse blown; (b) broken wire or connection in the wiring to the machine; (c) piece of foreign matter under a brush; (d) brush stuck in holder; (e) brush spring out of action; or (f) the open circuit may be in some part of the motor itself.

By careful observation or by testing for continuity, the nature and location of the open circuit can easily be discovered.

A Short Circuit.

Amongst the most common short circuits are the short-circuiting of (a) armature coils; (b) commutator bars; (c) field coils; (d) a shunt or compound wound motor, connected so that the armature is in circuit, but not the field windings. Should some of the armature coils or commutator bars be shorted, the machine would start turning and would then stop.

When starting only takes place with heavy current, accompanying sparking, and acceleration occurs with small load, it is an indication that a field coil is short-circuited.

A Wrong Connection.

A common mistake, made in the connecting of starters for shunt and compound wound motors, is the interchanging of the armature and line wires at the terminals of the starter. The line wire is often placed in the armature terminal and the armature wire to the line terminal. When this is the case, on closing the main switch and advancing the starter arm to the first contact, the field is connected in shunt across the armature of the motor, and the pressure applied to the field is therefore only the voltage between the brushes. At starting nearly all the main voltage is absorbed in the starting resistance, and the pressure across the brushes is therefore only very small; therefore as a direct consequence, only a very weak field is the result, which means that the motor will not start with the starter arm on the first or even second contact. Careful checking of the connections is necessary to make certain this mistake has not been made. It is very easy to get wires interchanged accidentally and especially is this so if the wires are run through conduit or in any way bunched together; to minimise this risk it is always advisable to use wires having different coloured insulation for the respective parts of the circuits.

ALTERNATING CURRENT MOTORS.

The four groups of causes of failure to start given above as for continuous current motors apply also to the alternating current class of machines.

Failure of supply is just as likely to be the cause as with a direct current motor, and on the motor failing to start the continuity of the several circuits should be immediately tested for in the usual way.

Open circuits may also be due to the same causes as in direct current machines, and they are traced either by observation or testing.

Short circuits are extremely uncommon in alternating current machines, but when they do happen to occur they may be traced to their source by means of a detector. Wrong connections are also a very rare occurrence in A.C. motors, but if the failure to start still persists after making sure that it is not due to any of the three foregoing causes, the connections should be very carefully followed out, although wiring instructions and terminal markings leave little chance of going wrong, more especially with modern machines.

MECHANICAL FAULTS.

The mechanical faults in electrical machines may be divided into four classes:—

1. Bearings running hot,
2. Oil slinging,
3. Vibration,
4. Wear of the Bearings.

Bearings Running Hot.

The indication of this is, of course, high temperature of the brasses. The temperature should not rise above 70 deg. C. Where large machines are in operation it is usual to insert a thermometer in the bearing and this should be read and noted at regular intervals.

The causes of hot bearings are: faulty erection, that is, the bearings are not in alignment; bent shaft; dirt in the oil or the use of unsuitable lubricant. If necessary bring the bearings and shaft into proper alignment with one another and scrape the bearing brasses. Great care should be taken to see that the armature or rotor is set central with the poles in axial direction and that the clearance is even all round. A bent shaft is easily detected either by the uneven clearance between the rotor and stator as the former is revolved, or by taking out the rotor and spinning it in a lathe.

Dirt in the oil is one of the commonest causes of hot bearings, also the use of an oil that is too thick. Either of these will be shown by grooves worn in the brasses. The oil should be carefully drained off and the bearings washed out with paraffin, the bushes scraped if necessary and the bearing refilled with good dynamo oil. It is also advisable to pack the bearing to prevent the entrance of dust.

A hot bearing may sometimes be caused by the belt being too taut and the obvious correction in this case is the reduction of the tension on the belt. If this should result in a slipping belt check the particulars of the belt transmission in regard to belt width and speed ratio: the latter should not exceed about 6 to 1. Should slip still occur and the checking of the transmission show abnormal conditions, some other method should be arranged, e.g., countershaft, or some arrangement added, e.g., jockey pulley, to increase the tension on the slack side of the belt. Belt compound may sometimes be used with advantage, but it is not advisable to depend on this for compensating faults in an inherently badly proportioned drive. Where the belt has only a small arc of contact the driving power can be increased by covering the pulley with a strip of belting or brake lining.

Oil Slinging.

Where oil is thrown through the joints of the oil lid, the lubricating ring is either running too quickly or has too much side play. The use of a heavier and wider ring will correct this defect. The oil ring should have a total play of about one m.m. Oil escaping at the end of a bearing is an indication that there is too rigorous a ventilation of the rotating parts of the motor. The insertion of a packing ring or a washer will retain the oil and cause it to return to the well.

Vibration.

Vibration of the foundation or bedplate, particularly at high speeds, may be caused either by the rotating part not being sufficiently well balanced, a very uncommon defect in modern machines, or by a bent shaft, commonly the result of excessive tension on the belt or, again, by loose holding down bolts. The two latter faults are easily detected and the remedies are obvious.

Should the vibration only occur when the motor is running at high speeds, and especially if the machine vibrates when unloaded, the manufacturer should be asked to examine the machine and correct the trouble.

Wear of Bearings.

The wear of bearings can be detected by checking the clearances around the running circle of the rotor and stator portions of the machine. The clearance at various diameters in large machines should be measured and recorded at regular intervals. This is very essential, as systematic and close observations of this kind will give early indication of undue wear and prevent possibly serious breakdowns of the machines.

The use of ball and roller bearings in the smaller types of machines has of late years become a standard feature. They give very little trouble but they should be examined regularly and the cases filled up with good grease.

When replacing armatures, where the end shield carries the bearing, great care should be taken to see that the shaft bearing and faces are clean and the end shield bolts should be evenly tightened up.

Where electrical machinery is used in contact with acid fumes, as in the case of a gas driven station, all metal parts will be considerably affected in a short space of time. It is advisable that all exposed metal parts likely to be affected should be thoroughly tinned before the machines are installed in the station.

THE BRITISH INDUSTRIES FAIR, 1930.

Arrangements for the Heavy Section of the 1930 British Industries Fair in Birmingham are even more advanced than at this time last year, more than 60 per cent. of the space having already been let. About one-fifth of the firms have also taken advantage of the opportunity offered them to secure their stands for five consecutive years. This early reservation of the major portion of the space greatly facilitates the policy of grouping kindred interests which was put partly into operation last February and is to be considerably extended in 1930. The system of alignment recently introduced—by which all stands have frontage to straight avenues one-third of a mile long—was the first important step towards a new development of progressive grouping which will add to the convenience of trade buyers not only in bringing the leading industries more closely together, but also in permitting allied trades to congregate in proximity to them. The new scheme, moreover, is so devised, taking into account the proposed building extensions for 1930 and future Fairs, that any industrial section can automatically expand to any dimensions, still retaining its unity of interest without disturbing the similar grouping of any other section. The principal officers of the 1930 Birmingham Section are as follow: President, Mr. Walter Barrow (Cadbury Bros., Ltd.); vice-president, Mr. John Bellis, M.I.Mech.E. (Belliss and Morcom, Ltd.); chairman of the Fair Management Committee, Mr. E. W. Bache (Geo. Salter, Ltd.); vice-chairman, Mr. C. Holland Harper (John Harper & Co., Ltd.); deputy-chairman, Mr. G. N. Guest, M.I.Mech.E. (Hollings & Guest, Ltd.); hon. treasurer, Mr. C. E. Greener (W. W. Greener, Ltd.).

NEW METRO-VICK PREMISES IN NEWCASTLE.

As from Monday, June 17th, the Metropolitan-Vickers Electrical Co., Ltd., and their associated Company Metro-Vick Supplies, Ltd., will occupy the new premises which they have built in Newcastle and which will afford much greater warehouse and office accommodation. The trade counter will be open from 8 a.m. to 6 p.m., but unfortunately, due to the severity of the past Winter, the new Showroom will not be complete until the end of August. The showroom in Saville Row will therefore be retained for the present.

The new address is Metro-Vick House, Northumberland Road, Newcastle-on-Tyne. Telephone, 6202/3/4/5 Central.

ALUMINIUM AND COPPER PRICES.

At the same time as the American cartel was imposing on the foreigner an increase of 80% in the price of copper, the Association of European Producers of Aluminium (a metal which rivals copper) was maintaining its price steady, and thereby placed the price of aluminium at a level of about half that of copper when measured by equal electrical capacity. (Extract from the speech made by Mons. P. Azaria to the General Meeting of the Compagnie Générale d'Electricité on the 8th May, 1929).—*La Vie Financiere,* 13th May, 1929.

Proceedings of the Association of Mining Electrical Engineers.

SOUTH WALES BRANCH.

Coal Cutting Machines in Low Seams.*

Discussion.

Mr. T. S. THOMAS congratulated Mr. Pring upon his thoroughly practical paper: he had left theory alone and spoken from his very extensive experience of coal cutters; he had also confined his remarks to D.C. Mr. Thomas said he would like to ask some questions regarding the sample piece of trailing cable exhibited, and which Mr. Pring had definitely claimed to be, in his opinion, the best form of cable to use with coal cutters. Surely, said Mr. Thomas, quite a number of engineers were definitely of the opinion that all metal coverings such as armouring should be avoided. In the event of the armouring becoming severed due to a fall of roof it would be a very difficult matter to again get earth continuity without robbing the cable of its flexibility. There was also the question of danger when, as the result of a fall the end of the armouring penetrated the insulation and came into contact with the conductor. For his own part he would prefer an ordinary C.T.S. cable. He believed that in some places in the Midlands they used copper braiding to act as an armouring. This was made up of a large number of fine wires, very similar to flex; but these were liable to penetrate through the rubber covering in the event of a fall, and there was also the danger of causing blood poisoning in the hands of the men who handled the fractured piece of cable. He, Mr. Thomas, was of the opinion that ordinary C.T.S. was more serviceable than the type of cable Mr. Pring had shown.

Mr. R. H. MORGAN.—Mr. Pring's remark that coal cutters were seldom overloaded was at variance with Mr. Morgan's experience. He held that coal cutters were practically always overloaded when starting and were subjected to various distressing factors during their cut; in fact, they may possibly be a colliery's most abused item. The lack of graded starting apparatus contributed to a heavy running-up load which made it necessary to have a generously rated overload toleration on the protective devices. This was frequently reflected in the tendency to burn out the motor should the machine become "stuck"; the use of a safeguarding time limit device being, he understood, not often used.

The improvements suggested by the Mines Department were desirable and the necessity for some of the recommendations reflected little credit upon those concerned with the design and maintenance of such apparatus. He believed that the more careful choice of machinemen would obviate much of the trouble experienced and considerably reduce the accident list.

Mr. Morgan said he could not follow the author's remarks regarding the relative temperatures of a useful fuse and one that "offers no safeguard."

Mr. Pring had advocated the locking of circuit breaker gate-ends to prevent unauthorised altering of the trip setting. This would be unnecessary with a decently designed circuit breaker in which such devices were enclosed within the tank.

The suggestion that the joint box pillars should be made previous to the installing of the cable was very nice, but is such accuracy of measurement possible with the irregularities of cable "slinging" in mining work? He, Mr. Morgan, failed to appreciate any adverse effect on cables from the variations in temperature, which were not excessive in a properly ventilated mine. The suggested danger to cable by repair men was surely not present if the cable were properly suspended so that it could easily be unhooked and laid upon the ground, and protected suitably for a distance comparable with the repair work being done. Mr. Pring's shyness of using bitumen cable for in-bye work was unwarranted. In the practice Mr. Morgan was acquainted with, wire armoured bitumen cable was taken right to the gate-end and was probably the most satisfactory of everything connected with coal cutting. With such cable the suggestion of a recess containing spare coils for extension would not, he feared, be desirable; the insertion of any necessary extra length and a joint box being more economical—quite apart from another effect of such coils on an A.C. system. Joint boxes with such cable were, of course, an absolute necessity. As distinct from the mentioned danger, the use of link boxes near the face was unnecessary with a well laid out network with its distribution boards and controls.

With regard to auxiliary earth plates: Are they asked for in the Coal Mines Act, or rather, was not the use of additional earth plates definitely deprecated?

Mr. HANNAH, speaking of trailing cables, said his experience was similar to that of previous speakers: the perfect trailing cable had not yet been produced. The sample single wire armoured cable, passed round at the meeting, had the disadvantage that if subjected to a blow or squeezed, the distortion of the cable remained permanent.

The Memorandum on the Electricity Regulations recommends the use of "Ferflex" braiding: he had found that the comparatively thin layer of cab tyre outside the braid tended to peel off; another fault was that the fine wires of the braid tended to pierce both the outside covering and the inside insulation. In the first case the men's hands were cut, in the second earths were caused. The plain cab-tyre cable without armouring or covering has the advantage that cuts can very easily be seen and repaired.

A paper of the type read by Mr. Pring was most opportune; nearly 50% of the electrical accidents in mines were due to the use of coal cutters, and there was no doubt but that practical papers of this kind were particularly valuable.

Mr. J. B. J. HIGHAM.—Mr. Pring stated that coal cutters were seldom overloaded. Assuming that the working conditions did not demand more than 30 H.P. or 50 H.P. then they were not overloaded but, on the other hand, a 30 H.P. or 50 H.P. motor in a coal cutter was not so liberally rated as the ordinary motor of the same output and speed. When employed on test work with a large manufacturing firm he remembered having seen certain coal cutting machines under test, and so far as the motors were concerned they were looked upon as "wash-outs." The motors were designed by experts, but even the expert could not put more than a certain amount of scientifically apportioned material into a given space. The space available was the inexorable limit in coal cutters for low seams.

Mr. Higham, continuing, said he would like to mention the matter of earthing. Mr. Pring had advocated earth plates in sump holes and he, Mr. Higham, questioned whether that would be sufficient: he did not consider a plate put into a sump hole could be accepted as a very efficient earth. Though the plate may be actually submerged in the water in the sump it did not follow that a good earth would be obtained.

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*See *The Mining Electrical Engineer,* May 1929, p. 376.

With regard to the use of two single core cables, instead of the usual twin core cable: Mr. Higham said he was not quite sure whether the reference was only to trailing cables or referred to the whole cable system, but on D.C. there was a distinct danger in using two cables, however well the armouring may be bonded. Extremely dangerous pressures were induced when tripping a large over-loaded motor, or when a switch at the surface, say, is clearing a short in-bye. If the trailing cables only were in the form of two single core cables then not much danger could exist. The proper thing to do, however, was to go in for twin core cable, take all necessary precautions, and have a completely metal enclosed system from beginning to end; adopting trailing cables in which each core was surrounded with a good form of flexible metallic covering. Under those conditions a short between cores was practically impossible, and if some form of leakage protection was adopted it required only a very small leakage current to trip the switch, with consequent reduction of dangerous "open sparking."

Mr. DAWSON THOMAS said he wished to congratulate Mr. Pring on bringing forward a paper illustrating how the adoption of electrical method was helping the industrial condition and increasing the output of coal. For years they had worked to increase the output, and Mr. Pring had emphasised one way. From that point of view alone he commended Mr. Pring for making such a stand for coal cutting by means of electrical power.

With regard to cables, Mr. Thomas said his experience with D.C. was that two separate cables were best. They were very accessible and can be quickly repaired. With regard to the point that coal cutters were not properly handled during the cut, that subject came right back to the work of the Association, one of whose duties it was to train men in the use of their machines.

With reference to the incoming cable, he certainly believed it to be beneficial to have a spare coil kept in a properly designed cutting so that it could be used when necessary, as, for instance, in the event of a fall. He had in mind the case of a colliery company, as far back as 1908, where it was insisted that before a cable was taken down it had to be made "dead," laid on the ground and covered with properly constructed timber. If such methods as those were insisted upon today there would not be so many accidents with electric coal cutters.

Mr. JOSEPH JONES, whilst appreciating the value of the paper, said Mr. Pring was a little behind the times as regards electric coal cutting in South Wales: he had referred to D.C. machines only. He did not think any colliery company would entertain putting D.C. coal cutters in a colliery to-day with a three-phase supply available. During the last fifteen years, Mr. Jones had not come across any colliery where D.C. coal cutting motors would be entertained in preference to modern A.C. squirrel cage motors.

With regard to earthing: the Coal Mines Regulations require the earthplates to be at the surface of the mines, and there was no necessity for earth plates being put in the sump. A sump was not necessarily a good earth. In some cases even a natural sump did not connect with any mass of earth, and to depend on that only instead of on proper safeguards entailed certain serious dangers. Regarding trailing cables he, Mr. Jones, was inclined to agree with other speakers that C.T.S. without any braiding satisfied the best requirements. With braided cables which had been severed it was difficult to make good the braiding and retain flexibility. Where the braiding was superimposed over the armouring it was particularly difficult and sometimes means the scrapping of the cable, which in to-day's economics was a matter that could not be entertained.

Regarding the use of fuses, Mr. Jones said he did not think there were many mines in South Wales where fuses were being used in-bye underground as a protection. It had been the practice of nearly all the inspectors to advise the cutting out of fuses, and the installing of overload protection devices immersed in oil included with the breaker. With regard to the type of man in charge of coal cutters he knew of a case where, fuses having blown, the machineman came along and producing a piece of ginger beer bottle wire said that was the sort of fuse to use: it would last much longer! From that point alone, fuses should be discarded entirely. Regarding the subject of remote control, personally from his experience he did not think it would be a very practical form of protection, and it was likely to meet with opposition for the reason that it would tend to introduce further complications.

Mr. BATES said the present state of the coal trade made it more essential than ever to apply all possible ways and means of reducing the cost of coal production, and the coal cutting machine would play a great part towards so doing in the future. Some were inclined to condemn the electrically driven coal cutting machine on the grounds that there was not sufficient room in them to house a motor capable of standing up to the heavy duties. From his experience he certainly could not agree. It was wonderful what the modern coal cutter motor, both A.C. and D.C., would do under the conditions they were oft-times expected to cope with. Any troubles experienced were not often due to overloading if proper consideration was given to the type of machine chosen for the class of coal or clod the cut had to be made in.

Mr. Pring had referred to single core cables, and presumably referred to D.C. supply: one would not think of using long lengths of single core cable along main roadways. There was, however, something to be said in favour of two single core cables on machine headings near the coal face where they were subject to frequent damage from falls, etc., and where repairs had to be made hurriedly, and often in a temporary manner, so as not to delay the cutting. Such repairs could be made more quickly and safely on single than on twin core cables.

About earthing systems he thought Mr. Pring referred to the auxiliary earth as a second precaution and not as the earthing system itself. A local earth offered certain advantages and he did not think the Coal Mines Regulations forbade the use of local earths. He understood that the system may have earths as often as may be wished provided it had a continuous earth circuit earthed at the surface. He had experienced a case where the earthing system was apparently in perfect order, yet, when an earth leakage occurred on a haulage motor, severe shocks and sparking were seen off the haulage rope some distance in-bye, due apparently to an insulating stratum in the ground between the two points. In that case, as is often found, water was lying on the roadway but the earthing system, which was the armouring of the cables, was slung up on the timber in the dry with no possible chance of local earthing. In such cases local earthing had advantages. For these reasons he thought local earthing should be advocated.

He agreed with Mr. Pring in his remarks about the gate end box. He, Mr. Bates, had found it to be the weakest link in the system: even to-day it was surprising to see the number of switch fuse types in use and still put forward by switchgear makers. A fuse, to be any protection for the motor, had to be of such a size that it was always fairly hot when carrying load. He had never seen a cartridge type in use in a gate-end box: the fuses were always of the porcelain handle type. The heat generated in the fuse, being enclosed in the air-tight casing, was conveyed to the fuse contacts which lost their tension; the resulting bad contact soon became another source of heat and deterioration rapidly followed until the whole interior had to be frequently renewed. To avoid this, heavier fuse wire was often put in, then when a short occurred the fuse handle was blown to pieces and the severe arc, often carried over to the casing, caused an internal short; and, in some cases, fused a hole in the casing itself. This became therefore a source of extreme danger in the safety lamp mine near the coal face. The value of the broad machine flange flame-proof joint was also often destroyed by the frequent opening of the cover to change fuses, grit entered and wide gaps were left which permitted the internal flash to escape. The oil immersed loose handle circuit breaker type was certainly much safer, as the cover could be kept locked. The coal cutter attendant had only to operate the external handle to re-set the switch and could not interfere with the setting. There was a danger on a D.C. supply, owing to the frequent operating of the switch, for the oil to carbonise and cause trouble. Being generally at the extreme end of the system they were liable to be neglected.

There was on the market a very good air-break flameproof gate-end box which he, Mr. Bates, had had in use now for a few years. They stood up to their work exceedingly well and required very little attention. The switch was also fitted with no-volt release and a time limit device.

A great deal had been said about trailing cables. From his experience he preferred to use the ordinary C.T.S. with an earth core. He had always found an outer armouring or an earthing shield over cores to give extra trouble and very little, if any, safer or better protection.

Mr. J. B. J. HIGHAM, at this stage, said he would like to be permitted to comment upon the point Mr. Bates and a previous speaker had raised regarding the number of auxiliary earth plates that may be used. His, Mr. Higham's, interpretation of the particular Regulation is: an earth plate must be situated at the surface, that is definitely stated; to this earth plate the *earthing system* must be connected. The earthing system is understood to be armourings of cables, frames of motors, etc., in fact, every metallic covering and enclosure of the conductors of a power system. Some transformer cores and parts of other electrical apparatus, although not enclosures, come under this head.

Further, a system may be earthed or insulated. As an example of an "earthed" system, an "earthed" three-phase system is one in which the star point is earthed "at one point only," and that "one point" is to be earthed at the surface earth plate.

To explain this more clearly Mr. Higham stated a typical case as follows. A three-phase star connected generator is connected to a three-phase star connected transformer. Two star points are available, viz., (a) the generator star point, (b) the transformer star point. The point usually selected is the generator star point and the Regulations definitely prevent this point and the transformer star point being earthed at the same time. The point selected *must* be connected to the earth plate at the surface, but there is nothing in the Regulations to prevent the *earthing system* being connected to any number of auxiliary earth plates. These plates may be installed anywhere in or about a mine.

In his previous remarks he, Mr. Higham, was not objecting to auxiliary earth plates, but he did question the efficiency of an earth plate in a sump hole; there may be good contact between the plate and the water, but quite often good contact did not exist between the water and the general mass of earth.

Mr. S. B. HASLAM, in proposing a hearty vote of thanks to Mr. Pring, said he supported those members who had expressed a desire for more papers of this description. They were particularly suited to this Association. Papers which brought forward troubles which had been experienced by practical men, and the means they had adopted to overcome those troubles, induced free expression of opinion from other practical men and thus the needs of the Association would be looked after in the best possible way.

Mr. C. F. FREEBORN, in seconding the vote of thanks, emphasised the advisability of putting before the Association practical papers of this kind. One of the strongest forms of evidence in favour of this paper was the contribution made by Mr. Bates, who as a practical man probably had more experience of coal cutters in the early days than anyone else present. The way in which Mr. Pring had treated the subject was far more to the liking of the average practical man than would be a study of the economical points such as A.C. versus D.C., etc. On behalf of the motor maker, if one took the trouble to study the present situation, it would be evident that the makers of coal cutters to-day have achieved most remarkable results in getting the power that is required into such a small space. Mr. Pring was, in a sense, to be envied for having a D.C. circuit, as D.C. machines have a slightly better torque characteristic than A.C. machines, although the introduction of the high torque squirrel cage motor has gone far to equalise matters. That subject alone was worthy of a paper to itself.

With regard to trailing cables, Mr. Freeborn said he was surprised to find so few of the cable men present referring to the subject, which alone could be made the subject of a paper. The control of coal cutters also could be dealt with separately, and the electrification of coal faces could not be dealt with in one, two or even half-a-dozen papers. The question had been raised as to whether there had been any fatal explosion from coal cutters; he believed one was reported in last year's Inspector's Report. In one instance, to his definite knowledge, a coal cutter caused an accident which was fatal to two people, and it was the cause of the colliery almost deciding to scrap all their electric cutters and put in compressed air. However, the problem was put up to several electrical manufacturers, and between them they involved a system which enabled the colliery to go forward with their existing coal cutters, but with much more effective and protective devices.

Mr. F. E. PRING, in reply to Mr. Morgan's remarks on overloading, said it was usual before installing a coal cutter to go into the conditions under which it would have to work. The right type and size of motor to meet these conditions is selected, and with a practical machineman in charge it was rare that the motor need get overloaded.

In reply to the criticisms of Mr. J. Jones, Mr. Pring said he was aware of the requirements as to surface earth plates, but had proved the advantages of auxiliary earth plates placed in sump holes along headings, as an addition to the existing earth system. As to concrete sump holes, he had never come across a sump hole made of concrete along main headings, but they would be useless from an earthing point of view; he would not agree to an earth plate being placed in a concrete sump hole because it would limit the area of earth contact and practically confine contact to the water only. His point was that a full area of contact is made in the saturated earth surrounding the sump hole.

Mr. Pring said his preference for armoured trailing cables was based on practical experience, not only of this type but with the unarmoured type also. He had found them last as long again as the ordinary unarmoured cab tyre. Should the armour wire break it would be liable to damage the men's hands, but it very seldom did break, and then the cable was taken up to the surface and properly repaired. Armoured cab tyre trailing cables have a much longer life than those of plain cab tyre, and that item had to be considered, for costs were always of first importance.

SOUTH WALES BRANCH.

Ⓟ Power Factor—Its Cause and Effect.

C. L. JAMES.

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

Power Factor is the relation in an alternating current circuit of the true watts to the apparent volt-amperes. In the first it will be advisable to endeavour to show why there may be a difference between the *true* power of an A.C. circuit and the *apparent* power derived from multiplying volts by amperes.

Inductive Circuit.

In direct current working the magnitude of the current flowing in any circuit for a given electro motive force is inversely proportional to the resistance of that circuit under all conditions; but in alternating current working this does not hold true if the circuit is an inductive one because another property, known as inductance and which is due to electro-magnetic reactions, has to be taken into account. An inductive circuit is defined as a circuit which requires a greater alternating pressure or voltage to send a given current through it than it does a direct current pressure to send the same current through a similar circuit. An inductive circuit, therefore, may be said to offer more obstruction to the passage of an alternating current than it does to a direct current. One, therefore, comes to the conclusion that the obstruction presented to an alternating current by an inductive circuit exceeds that due to the resistance of the circuit. It is on this account that the principles of self-induction play such an important part in alternating current working.

It has been stated that a greater alternating current pressure is required to force a given current through a circuit than it does a direct current pressure.

The cause of this phenomenon is not difficult to trace if we apply the first laws of electro-magnetic induction when considering it. It is a well known fact that the passing of electricity through a conductor causes a magnetic field to be set up around the conductor; the character of the field will be the same as the current producing it. It then follows that, when the current is alternating, the magnetic field will also be alternating, and changing at the same rate or frequency as the current. This brings us to a point where we can apply two of the fundamental laws of electro-magnetic induction. These are known as Faraday's Law and Lenz' Law.

Faraday's Law.

This states that whenever relative motion takes place between a conductor and a magnetic field in such a manner that the lines of force linked with the conductor vary, an electro motive force is induced in the conductor, the magnitude of which E.M.F. is proportional to the time rate of change in the number of lines of force linked with the conductor.

Lenz' Law.

This states that, in all cases of electro-magnetic induction, the direction of the induced currents is always such as to tend to stop the motion producing them.

So by applying Faraday's Law we see that there is an electro motive force induced in the circuit, as there is a magnetic field which is alternating in magnitude, and it also cuts the conductors in the circuit. Its magnitude will be equal to 2π f.L.I. where 2π f. is the greatest time rate of change of the magnetic field in radians per second:

L is the Inductance of the circuit;
I is the current flowing.

L, the inductance, can be calculated, say for an ordinary solenoid, in the following manner:—

Where B = Flux density per sq. cm.
U = Permeability.
H = Magnetising force.
l = Length of magnetic path in cms.
a = Cross sectional area of core in sq. cms.

$$L = \frac{\text{Flux linkages per ampere}}{10^8}$$

$$B = UH \text{ and } H = \frac{4\pi}{10} \times \frac{AT}{l} = \frac{1.257\ AT}{l}$$

$$\therefore \text{Total lines of force} = \frac{1.257\ AT}{l} \times U \times a$$

As L = Flux per ampere × number of turns linked × 10^{-8}

$$= \frac{1.257 \times \text{Turns} \times U \times a}{l} \times \text{Turns} \times 10^{-8}$$

$$\therefore L = \frac{1.257 \times (\text{Turns})^2}{l} \times U \times a \times 10^{-8}$$

It therefore follows by the application of the Lenz' Law that the induced electro motive force is in the nature of a counter or back electro motive force. It is called an E.M.F. of self-induction, since it is due to the inductive action of the current upon itself, and inasmuch as its magnitude is proportional to the time-rate of change in the number of linkages producing it, it follows that its maximum value occurs when the rate of change of the current is a maximum. The greatest rate of change of the current is when it passes through its zero value, so it follows that when the current is passing through its zero value the induced electro motive force is a maximum. Therefore the E.M.F. of self-induction lags behind the current by a quarter of a period, that is 90 degrees.

It is agreed that when an alternating current flows in an inductive circuit a back electro motive force is set up. Therefore, to allow the current to flow there must be applied an electro motive force equal but opposite to the back electro motive force, apart from the electro motive force required to overcome the resistance of the circuit. It can therefore be said that the impressed E.M.F. in an inductive alternating current circuit is made up of two components. The E.M.F. required to overcome the resistance of the circuit, and the E.M.F. required to neutralise the back or reactive E.M.F. The E.M.F. to overcome the resistance of the circuit is in phase with the current, but the E.M.F. required to neutralise the reactive E.M.F. will be 90 degrees in advance of the current, as the reactive E.M.F. lags behind the current by 90 degrees.

We now ask the question, what will be the phase relationship between the impressed E.M.F. and the current, as there is one component in phase with the current and the other leading by 90 degrees?

By the use of vector diagrams, and the parallelogram of vectors, it is quite easy to find the magnitude of the applied E.M.F. and also the angle by which the applied E.M.F. leads the current, as is shown in Figs. 1 and 2; and by calculation, as the two components are in quadrature:—

$$\text{The applied E.M.F. } (E_T) = \sqrt{E^2_R + E^2_L}$$

$$\text{i.e. } E_T = \sqrt{(IR)^2 + (2\pi f. L. I.)^2}$$

$$= I\sqrt{R^2 + (2\pi f. L)^2}$$

and from a vector diagram it can be seen that:—

$$\text{Tan } \theta = \frac{2\pi f. L. I.}{IR} = \frac{2\pi f. L}{R}$$

$$= \frac{\text{Reactance}}{\text{Resistance}}$$

The Measurement of Power.

The measurement of power in direct current working is Volts × Amps = Watts. This does not hold true in alternating current working, as there is a part of the applied E.M.F. used to neutralise the effect of the reactive E.M.F.

Therefore, the power in an alternating current circuit is Current × Electro Motive Force required to overcome the total effective resistance.

It can also be seen from a vectorial diagram that the E.M.F. required to overcome the total resistance is equal to the applied E.M.F. × Cosine of the angle of phase difference between the applied E.M.F. and the current, as the E.M.F. required to overcome resistance is in phase with the current.

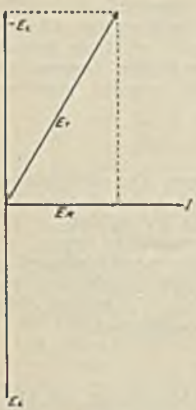

Fig. 1.

Fig. 2.

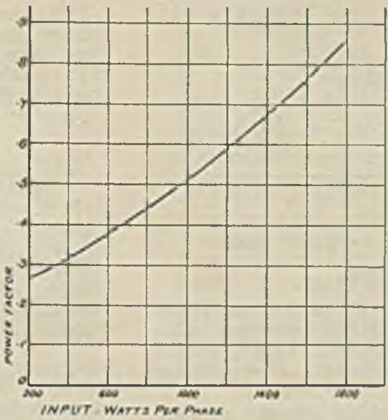

Fig. 3.

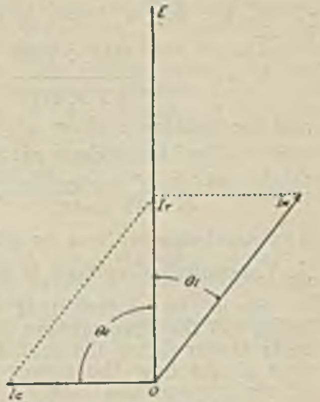

Fig. 4.

So the true power in an alternating current circuit is:—

Impressed E.M.F. × Current × Cosine θ

and it is Cosine θ that is called the Power Factor, as it tells us what percentage of the applied voltage is available to overcome resistance.

So it can be seen that the product of the volts and amperes as given by the switchboard instruments will not be the true power in an alternating circuit, as they do not take into account the phase relationship of the applied E.M.F. and the current.

As Volts × Amps × P.F. = True Watts

$$\text{Power Factor} = \frac{\text{True Watts}}{\text{Volt Amps}}$$

$$= \frac{\text{Watts dissipated}}{\text{Volt Amps applied}}$$

It can be quite clearly seen that the power factor of a circuit will depend upon its inductance, and as the inductance is proportional to the flux linkages, it is evident that there can never be unity power factor in any circuit in which there are coils of wire carrying an alternating current (except by the use of special apparatus). Therefore it follows that a highly inductive circuit will have a low power factor.

Causes of Low Power Factor in Colliery Plants.

The chief causes of low power factor in colliery plants is the running of induction motors and transformers on no-load or only partially loaded, such as occurs in screening and hauling plants where the motors are running light for considerable periods. The power factor of induction motors and transformers is much lower on no load than on full load, as is shown in Fig. 3, which indicates the values of the power factor of an induction motor from no-load to full-load. It will be noticed that the power factor is as low as 0.28 on no-load, and rising to 0.86 on full-load. This is due to the effect of the magnetising current which is almost purely inductive, and as this is practically a constant quantity for all loads, the effect is not so marked on full load.

Effects of Low Power Factor.

The chief effect of low power factor is that it involves an increased amperage of current for a given power, consequently larger cables, heavier switchgear, and greater generator and transformer capacity are required to meet the increased current. It also shows itself in the voltage regulation of generators, transformers and transmission lines. A much closer regulation is possible with a high power factor than with a low one. This will be more fully dealt with later on.

Power Factor and the Power User.

In the foregoing notes it was stated that low power factor increases the current for a given power. How does this affect the power user? With a low power factor the carrying capacity of cables and switchgear will have to be greater than with a high power factor, for a given power consumption. This means greater capital costs for cables and switchgear, and again, the supply authorities have to instal plant capable of carrying all the current flowing in their mains. So they encourage consumers to keep a high power factor, by basing their charges partly upon a maximum demand in K.V.A.; and therefore by this system it pays the consumer to keep as high a power factor as possible. Let us consider a consumer who consumes 200,000 units per annum and having as his maximum load 60 K.W. at 0.6 power factor, that is 100 K.V.A. The supply authorities' charges are 0.5d. per unit consumed, plus a maximum demand charge of £5 per annum per K.V.A. The consumer's electricity costs per annum will be:—

	£	s.	d.
200,000 units at 0.5d. per unit	£416	13	4
100 K.V.A. at £5 per K.V.A.	£500	0	0
Total Costs	£916	13	4

Now if the power factor were 0.9 the maximum K.V.A. demand would be reduced to

$$\frac{60 \text{ K.W.}}{0.9} = 66.6 \text{ K.V.A.}$$

and the annual costs would be:—

	£	s.	d.
200,000 units at 0.5d. per unit	£416	13	4
66.6 K.V.A. at £5 per K.V.A.	£333	0	0
Total Costs	£749	13	4

showing an annual reduction in costs of £167.

Effect of Power Factor on Transmission.

Low power factor adversely affects the voltage regulation of the transmission line, as can be seen in the following example.

500 K.W. is to be transmitted 6 miles. The voltage at the consumer's end is to be 6000 volts and the power factor is 0.6.

Assume resistance of line to be 10 ohms, and the Reactance of line as 5 ohms.

$$\text{Current per conductor} = \frac{500 \times 1000}{\sqrt{3} \times 6000 \times 0.6}$$

$$= 80 \text{ amps.}$$

Reactance drop per conductor = 400 volts.

Resistance drop per conductor = 800 volts.

Impedence drop per conductor $= \sqrt{(800)^2 + (400)^2}$

$= 895$ volts.

$\therefore$ Drop in potential difference between two conductors of the line $= \sqrt{3} \times$ drop per conductor,

$= \sqrt{3} \times 895 = 1548.3$ volts.

Therefore the voltage at the transmission end would have to be $6000 + 1548.3 = 7548.3$ volts.

If the power factor were unity, the current would be:—

$$\frac{500 \times 1000}{\sqrt{3} \times 6000} = 48 \text{ Amps,}$$

and the Reactance drop per conductor = 240 volts

Resistance drop per conductor = 480 volts.

$$\text{Impedance drop per conductor} = \sqrt{(480)^2 + (240)^2} = 535 \text{ volts.}$$

$\therefore$ Drop between lines = $\sqrt{3} \times 535$ = 925.5 volts.

$\therefore$ Transmission voltage is 6,925.5 volts.

So it can be seen that with a P.F. of 0.6 the regulation of the transmission line is 25.8%, whereas with unity power factor the regulation is 15.4%. This example thus shows how the power factor affects the regulation of the transmission line.

Consider the transmission problem from another point of view. The current flowing in a conductor varies inversely as the power factor; so with a low power factor the current carrying capacity of a conductor will have to be greater than with a high power factor, as the following example shows.

Assume that 500 K.W. is transmitted at 6000 volts three-phase, with a power factor of 0.9.

$$\text{K.W.} = \frac{\sqrt{3} \times \text{volts} \times \text{amps} \times \text{P.F.}}{1000}$$

$$\text{Current per conductor} = \frac{500 \times 1000}{\sqrt{3} \times 6000 \times 0.9} = 53.7 \text{ amps.}$$

If the power factor fell to 0.6 the current per conductor would be:—

$$\frac{500 \times 1000}{\sqrt{3} \times 6000 \times 0.6} = 80 \text{ amps.}$$

If the line were designed to carry 500 K.W. at 0.9 P.F., that is 555 K.V.A., and the power factor of the load fell to 0.6, the line would be called upon to carry 833 K.V.A., which means that the line would then be overloaded by 833 — 555 = 278 K.V.A.

Effect of Power Factor on Generators.

With a lagging or leading power factor the amount of true power delivered by a generator is less than the kilo-volt-amperes, with the result that the generators may be fully loaded in regard to amperes or current output, and therefore of temperature rise, but they would not be delivering their full load of true power. So a low power factor reduces the kilo-watt capacity of the plant, as can be seen by the following example.

Consider an alternator designed to carry 1000 K.W. at 0.8 P.F. (i.e., 1250 K.V.A.). The actual power factor of the system is 0.6.

When the alternator is producing its full load rating in K.V.A. (i.e., 1250 K.V.A.) the true kilo-watt output will only be 750 kilo-watts. So here is an example of a machine working under full load conditions and yet its true power output is only 75% of its kilowatt rating.

If the machine were producing 1000 kilowatts of true power at 0.6 power factor, the kilo-volt-amps. output would be raised to $\frac{1000}{6}$ = 1666.6 kilo-volt-amps., whereas the generator was designed to generate only 1250 kilo-volt-amps.; so that the machine would be overloaded by 1666.6 — 1250 = 416.6 K.V.A., i.e., 33%. So the stator copper losses of the machine would be increased, which would cause serious overheating as well as a decrease in the efficiency of the alternator. Also a low power factor causes a large drop in volts in the alternator, partly because of the armature synchronous reactance, and partly because of the demagnetising effect of armature reaction. As a result the excitation on low power factor has to be much greater than on high power factor, in order to maintain the rated terminal voltage. This causes extra losses in the field system, and often times the overloading of the exciter when the alternator is not producing its maximum load of true power.

So it is clear that a low power factor lowers the plant efficiency and also increases the capital cost per kilowatt of generating plant capacity.

Power Factor Correction.

After so much has been said about the detrimental effects of low power factor, it is only natural that one should come to consider the methods by which a low power factor can be improved. Fortunately there are a few well proved methods which can be employed to improve a low power factor. In colliery plants the two commonest methods employed are the installation of either synchronous motors or static condensers.

The Synchronous Motor.

A synchronous motor can be considered as an alternator run as a motor. Direct current excitation is supplied to the field exactly as with an A.C. generator, the necessary driving torque being obtained by current flowing from the line to which the stator is connected. By over-exciting the synchronous motor the current taken by it can be made to lead the applied voltage. Therefore if a synchronous motor is installed in a system which has a low power factor, and the excitation adjusted so that the motor takes a leading current from the line, the result will be that the power factor of the system will be improved because of and in proportion to the resultant of the lagging current taken by the asynchronous machines and the leading current taken by the synchronous motor. As the synchronous motor is a constant speed machine its usefulness for doing mechanical work is limited to driving such items of plant as the ventilating fan, or such other items of plant as may be driven at a constant speed. Therefore from the point of view of power factor correction its usefulness is mainly confined simply to the improvement of the power factor of the system. It will not relieve, say, the cables leading to the haulage motors of any of the current flowing in them.

The Static Condenser.

The other method of power factor correction employed in colliery plants is the installation of static condensers. These have a wide range of usefulness from the point of view of power factor correction. The static condenser operates by absorbing a certain amount of power, the current being practically pure capacity current and leading the applied voltage by 90 degrees. Therefore if a condenser of suitable capacity be connected across the terminals of an induction motor, the resultant current of the condenser current and the motor current will be in phase with the applied voltage, and will have a lower value than before the condenser was inserted, as can be seen by Fig. 4. In the diagram OE is the applied voltage, OI_M is the motor current lagging by an angle θ_1, OI_c is the condenser current leading the applied voltage by an angle θ_2. A little consideration of Fig. 3 will show that for a motor current less than OI_M the motor will be over-compensated and a leading current will flow in the cable, which is as detrimental as a lagging current. The following is an example showing the advantages to be gained by installing a bank of condensers across the terminals of a three-phase induction motor.

Assume that a certain motor takes 66.6 K.V.A. at 0.75 P.F. the supply is at 440 volts, 50 cycles, and it is desired to raise the power factor of the motor so that the current flowing in the cables is a minimum.

True Power Input of motor = 66.6 × 0.75 = 50 K.W.

$$\text{Current} = \frac{50 \times 1000}{440 \times \sqrt{3} \times 0.75} = 87.4 \text{ amps.}$$

True Current Input = total current × Cos θ

= 87.4 × 0.75 = 65.5 amps.

$$\text{Wattless Current} = \text{total current} \times \text{Sin}\ \theta$$
$$= 87.4 \times 0.65 = 56.8 \text{ amps.}$$

Therefore the condenser current must be 56.8 amps. per phase.

$$Ic = 2\pi f.E.C$$
$$C = \frac{56.8 \times \sqrt{3} \times 10^6}{2\pi \times 50 \times 440} = 710 \text{ Microfarads per phase.}$$

Therefore, if the three condensers each of 710 microfarads capacity are connected in delta to the motor terminals, the current flowing in the motor cable would be reduced by 87.4 — 65.5 = 21.5 amps., and the copper loss in the cable would be reduced in the proportion of $(65.5)^2$ to $(87.4)^2$.

These notes have been written on power factor correction as being merely a brief survey of the two systems employed in colliery plants for the improvement of its system of power factor. The author would particularly invite opinions and views as to what may be considered the best method of power factor correction or improvement.

AYRSHIRE SUB-BRANCH.

Some Advantages of Power Factor Correction.

H. FERGUSON.

(*Paper read 19th January*, 1929).

In these days of keep competition when the cost per ton or per article is subjected to such keen scrutiny, the cost for electrical energy plays an important part in the economical running of a colliery or works. Alternating current is now very rapidly displacing direct current, especially for power work and more particularly where fairly long transmissions are required. Not only is alternating current machinery more reliable but the flexibility of such systems is much greater than that of direct current systems, and large powers may be transmitted at high pressures with a minimum of loss and transformed down to suitable voltages for general use

With the extended use of alternating current the question of power factor is receiving much more attention than formerly and consequently Corporations and Electric Supply Authorities are now, in most cases, embodying power factor clauses in their agreements with consumers. The chief reason for paying so much attention to power factor is due to the fact that a consumer's plant operating at a low power factor causes a considerable loss on the distribution system. This loss is due to the wattless current which, although doing no useful work has, in addition to the actual load, to be carried by the transmission lines, transformers and other plant, and which current may be very considerable.

As a general rule alternators are rated to give a certain kilowatt output at a power factor of 0.8, and it can readily be seen that if the power factor of the system is, say 0.6, the alternator will become seriously overloaded if it is called upon to deal with a load of its rated kilowatt output at a power factor of 0.6. When calculating the K.V.A. rating of an alternator, the iron and I^2R losses are taken into account incorporating at the same time, sufficient ventilation in the machine to keep these losses within the margin necessary to ensure that the temperature rise does not exceed the B.E.S.A. limits. As the load in an alternator increases it is necessary to increase the field excitation in order to hold the voltage at its normal value. Consequently under heavy overload conditions very heavy excitation will be required, resulting in the overheating of the windings.

The question of power factor is of utmost importance to engineers in charge of electrical plant at collieries, works, etc., if they are to run their installations on an economical basis. Where an installation is operating at a low power factor, switchgear, fuses, cables, etc., will have to be much larger than should be actually required for the useful load, as they will require to be capable of carrying the extra, or wattless, current. In the case of a consumer who may be penalised by a Supply Company for low power factor, the cost of electrical energy will be much greater than if the installation were operating at the normal, or specified higher power factor.

When discussing power factor, the author has found in many cases that engineers are apt to confuse the term with that of load factor, but there is no real relationship between these terms.

Load Factor is the ratio of the average load to the actual rated full capacity of an installation. For example, a colliery installation having a number of motors, the "name plate rating" of the total being, say 500 H.P., is found to have an actual average demand of only 200 H.P. To find the load factor the following formula is applied:—

$$\frac{\text{Average demand}}{\text{Name plate demand}} \times 100 = \frac{200}{500} \times 100 = 40\%.$$

An alternative method of calculating the load factor of an installation is as follows:—

$$\text{Load Factor } \% = \frac{\text{Units consumed} \times 100}{\text{Maximum demand (K.W.)} \times \text{hours}}$$

By this method if the K.W.H. units consumed in a 30-day month were 50,000 K.W.H., with a maximum demand of 200 K.W., then the load factor (%) would be:

$$\frac{50{,}000 \times 100}{200 \times 24 \times 30} = \frac{5000}{144} = 35\%$$

Power Factor, on the other hand, is the ratio which true load bears to apparent load, or the ratio of kilowatts to kilo-volt-amperes. This explanation is generally sufficient for the trained engineer, but it is not very intelligible to the non-technical man. A rather unique way of explaining power factor was given in a recent copy of the Clyde Valley Electrical Company's magazine, to this effect. It is well known that in a glass of beer there is always a certain amount of froth, depending upon how the glass was filled. This froth may be called the wattless, or useless current of the beer. The ratio of the beer to the full glass, including froth, is therefore the power factor of that beer.

A method employed by a number of supply companies is to charge on a maximum demand K.V.A. basis, plus a small charge per unit consumed. Under these conditions, a consumer whose installation is operating at a low power factor pays at a higher rate than one whose installation has a higher power factor. Take for example an installation having a maximum demand of 200 K.V.A., operating at a power factor of 0.5, and with a demand charge of 30s. per K.V.A. per quarter; this would amount to £300 per quarter. Now, if the power factor were raised to, say .8, the K.V.A. maximum demand would be reduced to 125, showing a saving of £112 per quarter. Further, if the improvement were continued to unity power factor the quarterly charge would be only £150, or exactly half the original demand charge.

The method of checking the K.V.A. demand is by means of a maximum demand meter. The Aron meter, or the Reason Thermal Type Demand Indicator are the most universally used. These meters are usually of the half-hour lag type, the meter registering the highest demand of any one period.

When a watt-hour meter and a K.V.A. meter are fitted, the power factor of an installation can be checked from the readings of these two meters. For instance, in the case of a consumer whose installation has a K.V.A. demand of 400 K.V.A., and a kilowatt demand of 300 K.W., the power factor is the ratio of the kilowatts to kilo-volt-amps., and may be calculated as under:—

$$\frac{\text{K.W.}}{\text{K.V.A.}} = \frac{300}{400} = 0.75 \text{ power factor.}$$

Another method of penalising a consumer whose installation has a low power factor, is on the sliding scale basis; the consumer is metered by a three phase meter and also two single phase meters. The method is to take the units registered on the three phase meter over a quarter and charge at a flat rate of, say, 2½d. per unit at 0.8 power factor. The power factor of the installation is checked by means of the two single phase meter readings, and is worked out from the ratio of these two readings. The power factor is obtained from the curve (Fig. 1). For example, an installation has a three phase meter for the measurement of units consumed, and also two single phase meters A and B. Over a period, meter A registers 20,000 units and meter B 5,000 units. The ratio $\frac{B}{A}$ is therefore $\frac{5{,}000}{20{,}000} = 0.25$.

From the curve the ratio of 0.25 is found to give a power factor of 0.69.

A varying scale of reductions in charges is arranged which may be as much as 0.16d. per unit for a power factor of unity, or on the other hand, an additional charge of 0.15d. per unit may be made on a power factor of 0.6. Take for example an installation which consumes 10,000 units per month, at 2½d. per unit the normal charge at 0.8 power factor would be £104 3s. 4d. If the power factor were improved to, say unity, the charge would be reduced by 0.16d. per unit, an amount of £16 13s. 4d., and the actual charge be only £87 10s. per month. On the other hand, if the installation were operating at a low power factor of 0.6, the charge would be increased by 0.15d. per unit, which would amount to £15 12s. 6d., and the charge would be increased to £119 15s. 0d. as against the normal charge of £104 3s. 4d.

When a K.W. maximum demand charge is made, the penalty for low power factor is generally based upon an increase in the charge made per kilowatt. The method usually employed is to charge an annual or quarterly rate per K.W. of maximum demand at a power factor of 0.8 to 0.85. To penalise a consumer for low power factor this charge is multiplied by 0.8 and divided by the consumers' power factor. It will be seen that this increases the resultant demand charge. For instance, take a load of 100 K.W. operating at a power factor of 0.7, with a charge of 40s. per K.W. maximum demand per quarter. Under normal conditions, that is at a power factor of 0.8, the quarterly standing charge would be:—

$$100 \text{ K.W.} \times 40\text{s.} = £200 \text{ per quarter.}$$

The consumer's power factor is, however, only 0.7, therefore the charge would be:—

$$100 \text{ K.W.} \times 40\text{s.} \times \frac{0.8}{0.7} = £228 \text{ 1s. 6d. per qrtr.}$$

This shows an increase of £28 1s. 6d., or approximately 14%, in the quarterly standing charge for a drop of 0.1 in power factor.

A bonus is offered for power factors over 0.8, in the form of a reduction in the K.W. charge. If in the case mentioned, of 100 K.W. at 0.7, the consumer improved this power factor to unity the quarterly standing charge would be:—

$$100 \text{ K.W.} \times 40\text{s.} \times \frac{0.85}{1.0}$$

$$= £170 \text{ 0s. 0d. per quarter.}$$

This shows a reduction of £30 0s. 0d., or 15% on the quarterly standing charges. The total saving, including the bonus for improved power factor, and the cancellation of the penalty for low power factor, is therefore £58 1s. 6d. per quarter.

It will be seen that no bonus is offered until a power factor over 0.85 is reached, as in the example given; the Supply Company allows a margin of 0.05 between the penalty and the bonus ratings.

From the foregoing examples it will be seen that when electrical power is being purchased, power factor becomes an important financial matter. It should be very carefully studied by the engineer in charge of the electrical installation, provided of course that the Supply Company has a power factor clause in its agreements and insists upon its operation.

It is not proposed to go very deeply into the technical side in this paper, but rather, by means of a few examples, to show why the question of power factor should receive adequate consideration. One of the principal causes of low power factor is the running of induction motors at a load much below their normal rated output. Until comparatively recently, and unfortunately not infrequently to-day, consumers bought and installed such motors regardless of their characteristics so far as power factor at various loads was concerned. Another mistake which is commonly made is to estimate roughly the size of a machine required and then to "add something" to be on the safe side. Under these conditions the machine never runs at the normal load for which it was designed and consequently it has a low power factor. Of course, one must except conditions when a machine much larger than that normally required may have to be installed for particular reasons. A colliery haulage, for instance, where the run is liable to be extended, and which would ultimately require the full output of the machine, or on looms, or other machinery requiring a heavy starting torque. Excepting under conditions such as these, there is really no excuse for installing a larger motor than that actually required when the drive has a fixed power, as in the case of pumps, etc.

With regard to the question of cables and switchgear, these are installed to carry a certain amperage and when the power factor of an installation is relatively low, they are forced to carry in addition a certain amount of wattless current for which there is no allowance usually made. For example, a shaft cable is required, and it has to be capable of carrying a load of 217 K.W. on a supply of 500 volts, 50 cycles, 3-phase. In order to arrive at the correct size of cable, it will be necessary to find the amperage per phase of the load. Assuming that the power factor is 0.5, the amperage per phase may be obtained from the following formula:—

$$\text{Amps. per phase} = \frac{\text{K.W.} \times 1000}{\text{V} \times \sqrt{3} \times \text{P.F.}}$$

$$= \frac{217 \times 1000}{500 \times 1.732 \times 0.5} = 500 \text{ amps.}$$

The cable therefore will, if paper insulated, require to have a cross sectional area of 0.3 square inches if it is to be capable of dealing with this load with any degree of safety. By improving the power factor to, say 0.8, the amperage per phase would be reduced to 316 amperes. This figure is obtained from the formula stated above, namely:—

$$\frac{\text{K.W.} \times 1000}{\text{V} \times \sqrt{3} \times \text{P.F.}} = \frac{217 \times 1000}{500 \times 1.732 \times 0.8}$$

$$= 316 \text{ amperes.}$$

A paper insulated cable having a cross sectional area of 0.25 square inches would be large enough to deal with this load. By improving the power factor still further to, say unity, the amperage per phase would be reduced to 240, as shown by the following calculation.

$$\frac{217 \times 1000}{500 \times 1.732 \times 1} = 240 \text{ amperes.}$$

A paper insulated cable of 0.2 square inches cross sectional area would then be large enough to carry this amperage with safety.

If a bitumen insulated, instead of paper insulated, cable were used, it would require to have a cross sectional area of 0.5 square inches. It will be seen that a cable having a much larger cross section is required if it is insulated with bitumen, as in this type of cable the permissible temperature rise is much lower than that of a paper insulated cable. This is due to the risk of de-centralisation of the cores, should the bitumen soften owing to excessive heating of the cable.

From the foregoing it will be seen that power factor plays no unimportant part in determining the size of cable required to transmit a given kilowatt load. The I^2R losses in a cable may be considerably reduced by improving the power factor of the load on that cable. For instance, on a cable of a given cross sectional area, the I^2R losses at a power factor of 0.7 on a kilowatt load are double that on the same kilowatt load at unity power factor.

Throughout the country there are many important industrial concerns which generate electrical energy for their own works, or collieries, and which have also realised the great benefit obtained from improved power factor. Very often it is found that an alternator is working up to its full load in amperes per phase, and possibly at only three quarters of its rated kilowatt output. In this connection a case which the author had recently showed the following position.

The installation consisted of an alternator having a rated output of 250 K.W. at 440 volts, 50 cycles, three-phase, at 0.8 power factor (or 317 kilo-volt-amps.). It was found that the main ammeter registered 420 amperes per phase which, from the formula

$$\frac{V \times A \times \sqrt{3}}{1000} = \frac{440 \times 420 \times 1.732}{1000}$$

= 320 kilo-volt-amps., which is slightly in excess of the full load (K.V.A.) rating of the alternator. The power factor of the load was tested and found to be 0.56. From the formula

$$\frac{V \times A \times \sqrt{3} \times \text{P.F.}}{1000} = \frac{440 \times 420 \times 1.732 \times 0.56}{1000}$$

the kilowatts = 179, which is considerably under the rated kilowatt output of the alternator (250 K.W.). The management had found it necessary to instal more induction motors to drive new machinery. They were, therefore, faced with the proposition of installing another generating set or improving the power factor of the present load. The latter proposition was adopted as being the most economical, and a static condenser equipment of 180 K.V.A. was installed. With this equipment in circuit the power factor was raised to 0.91 at a load of 179 K.W. The amperage per phase on the alternator was reduced from 420 to 258, thereby allowing for the installation of the new induction motors without having to instal a new generating set.

There are several methods of improving the power factor of an electrical installation; one of the first things to do is to examine all the motors to ensure that they are working as near as possible to their full load rating. If it is found that some motors are working at considerably less than full load output, these should if possible be changed to another drive. In a workshop where there are several motors driving lines of shafting, it is often possible to join up two or more of these by belting or other means, and to close down one of the motors. By such a judicious changing of drives it will often be found that a fair improvement in power factor can be obtained.

If the power factor is still low, and a penalty and/or bonus is available under the agreement, steps should be taken further to improve the power factor by introducing into the circuit some form of apparatus to give the required amount of rectification.

Improvement of power factor can be obtained by installing synchronous motors, phase advancers, compensated induction motors or static condensers. These four methods are the most generally adopted.

When selecting the most suitable apparatus to give the required rectification, the question of efficiency, losses, etc., should be very carefully considered. An economical method of power factor correction is by means of the synchronous motor, provided that the motor can be put to some useful work, such as driving a ventilating fan in a colliery. It can be readily seen that to run such a motor purely to obtain power factor improvement is fairly costly, as the running costs, losses and maintenance have to be taken into account. When considering a synchronous motor for power factor improvement, it should be noted that to obtain a leading component, fairly heavy excitation is required, with a consequent increase in the losses. With regard to the compensated induction motors, the same remarks, generally speaking, apply.

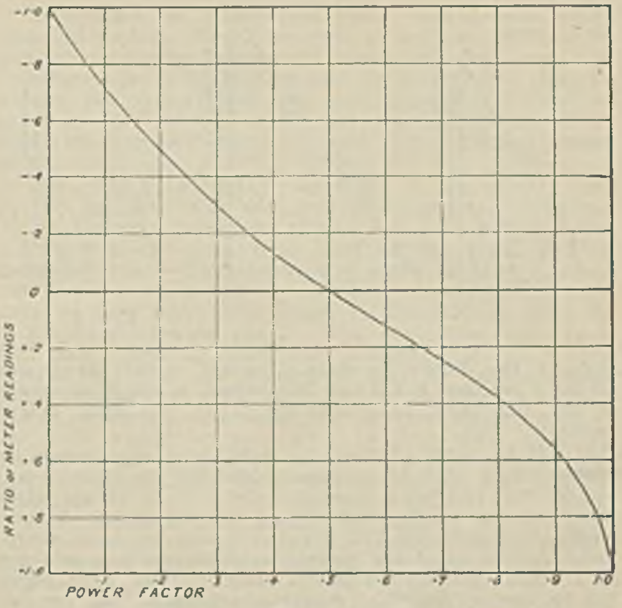

Fig. 1.

Phase advancers are applicable to slip-ring motors of 200 H.P. and upwards. The function of the phase advancers is to inject a leading current into the rotor of the machine and consequently a larger leading component is induced in the stator. The phase advancer has a further useful point in that it improves considerably the overload characteristics of the machine to which it is connected. A 200 H.P. motor is, however, a fairly large machine for which to find continuous work in the average installation.

Where conditions are such that no useful work, other than power factor correction, can be found for one of the above means of rectification, the static condenser is ideal.

Neglecting the maintenance charge, the losses in a static condenser do not exceed 0.5%, whereas with synchronous machinery the losses are generally from 3% to 4%. The condenser may cost initially more than the synchronous machine, but its higher efficiency makes it the more economical proposition.

Take for comparison a condenser having an output of 400 K.V.A. and a synchronous motor giving the same figure of power factor correction. The losses during a ten-hour day in the static condenser would be 20 kilowatt-hours which, at say 1d. per kilowatt-hour, would be 1s. 8d. per day, or £25 per annum. With the synchronous machine these losses would amount to approximately 120 kilowatt-hours per day, which would be equal to £150 per annum. The above figures are based upon the correcting apparatus being in circuit from eight to ten hours per day.

A case has already been mentioned showing the financial loss of operating at a power factor of 0.5, and that by improving the power factor to unity the cost was considerably reduced. It will be well to refer again to that case, as there is an economical limit to which power factor improvement may be carried. The load mentioned was 200 K.V.A. at 0.5 power factor and to

Fig. 2.

Fig. 3.

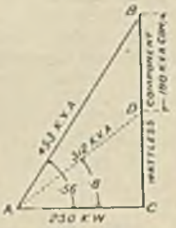

Fig. 4.

improve this figure to unity it would require apparatus giving a leading K.V.A. of 173, which is much in excess of the maximum kilo-volt-amps. (100) at unity power factor.

If it be assumed that the method of charging is by means of a K.V.A. maximum demand indicator, and should the rectifying apparatus be left in circuit after the load has been shut down, the maximum demand would be raised to 173 K.V.A. It can be seen, therefore, that to raise the power factor to unity would not be a sound proposition unless some method were adopted to ensure that the rectifying apparatus was not left in circuit under "light or no-load" conditions. It is, therefore, a question of calculating to what figure the power factor should be raised without the rectifying apparatus exceeding the new maximum demand in K.V.A. To improve the power factor of a 200 K.V.A. load from 0.5 to 0.87 would require apparatus giving a leading K.V.A. of 116. By improving the power factor to 0.87 the kilo-volt-amps. would be reduced to approximately 116. Therefore, the theoretical safe economical figure to raise the power factor of this installation to would be 0.87.

By referring to the vector diagram (Fig. 2) it will be seen that the condenser K.V.A. "B.D." does not exceed the load K.V.A. "A.D." at a power factor of 0.87, and is apparently within safe limits.

It is well known, however, that with a condenser in circuit under "light or no-load" conditions, the voltage has a tendency to rise above the normal figure. The capacity of a condenser varies as the square of the voltage, so that any increase in voltage will be reflected on the condenser, in that its capacity will be slightly increased. In practice, however, to ensure that the condenser K.V.A. capacity at any period will not exceed that of the load maximum demand kilo-volt-amps., the power factor of this installation should not be raised from 0.5 to a higher value than 0.86. In this case, the condenser would require to have a capacity of 113.9 kilo-volt-amps. to raise the power factor of a 100 K.W. load from 0.5 to 0.86.

With regard to the 250 K.W. installation which has been mentioned, the improvement was obtained by installing a static condenser having a capacity of 180 K.V.A. With this equipment in circuit the power factor was raised from 0.56 to approximately 0.91 on a load of 179 K.Ws. The object of raising the power factor to this figure was to ensure that at the full load of 250 K.Ws. the power factor would be maintained at a figure of not less than 0.8. The load at these works was such as to be conducive to low power factor, as during certain operations the full output of the motors was required, whereas at other operations the motors were running at comparatively low loads. The machines at these works were individually driven and it was not found possible to couple two or more of these together as the general lay-out and type of work done was unsuitable.

Referring to the vector diagram (Fig. 3) it will be seen that by the installation of the 180 K.V.A. condenser equipment, with consequent improvement of the power factor from 0.56 to 0.91 the K.V.A. on the alternator is reduced to 197, with a load of 179 K.Ws.

The vector diagram (Fig. 4) shows the K.V.A. of the alternator when the system is operating at a power factor of 0.56 with a load of 250 K.Ws. Let AC equal kilowatts, AB equal kilo-volt-amps., and BC equal the wattless component kilo-volt-amps. By installing a 180 K.V.A. condenser the wattless component K.V.A. is reduced by the amount BD, and the alternator K.V.A. is reduced to the value AD.

It is necessary to state that it is hardly possible to lay down any definite rules as to the type of apparatus most suited for power factor correction. Each proposition must be studied from all points, in order to ensure that the most suitable apparatus is used to give the required amount of rectification without increasing, rather than decreasing, the overall costs.

Generally speaking, when the required leading K.V.A. does not exceed 700 K.V.A., the static condenser is the most satisfactory solution to the problem. This is due to its exceptionally high efficiency, the losses being less than 0.5%.

In conclusion the author has to express his thanks to Messrs. British Insulated Cables, Ltd., for their assistance in supplying data and diagrams used in this paper.

Discussion.

Mr. G. N. HOLMES said the data given in Mr. Ferguson's paper should prove extremely useful for purposes of comparison by anyone obtaining electric power from a public supply company. He had been in contact with schemes regarding power factor and its correction in a good many instances and there were undoubtedly very large concessions to be obtained from most of the public supply authorities for improved power factor. The monetary advantage in some cases was so great that it would seem to be almost fabulous, and consumers were sometimes inclined to doubt the figures given them. Mr. Ferguson had mentioned two or three methods by which power factor could be improved, but from experience Mr. Holmes believed that condensers would be selected in at least 80% of the cases considered. The very high efficiency of the static condenser was in its favour as well as the low running costs. There was practically no maintenance charge whatever, and taken all through it was a very sound proposition. The synchronous motor had found favour in some collieries but in most cases it had been used for driving the ventilating fan and giving a continuous service of 16 hours a day. Mr. Ferguson had mentioned that where a condenser was too large for a plant the annual cost of current might go up considerably: he knew of one such case where a company, instead of finding the cost of their electricity reduced, found that it had gone up materially. This was a case of a K.V.A. maximum demand charge and where the condenser installed was much too big for the job.

Mr. UPTON.—The question of power factor has to be considered both from the point of view of the public supply undertaking and that of the consumer. There are so many phases of the power factor question that one becomes almost bewildered in trying to think clearly of them. At the present time they were looking at the national aspect of public supply and there was to be a wholesale linking up of undertakings. Of two such undertakings to be linked up one would have, say, an average power factor of between 80% and 90%, and the other perhaps only 60%. The conditions under which the one undertaking was running were very much more advantageous than those of the other. The man responsible for the undertaking with the low power factor had to consider remedying his defect: that is, he had to correct the power factor, and he was in rather a difficult position. By introducing static condensers or rotary condensers or other forms of corrective apparatus he could bring his power factor up to a reasonable figure that would enable him to link up advantageously. But he was not improving the power factor on his distributing system.

As an illustration, Mr. Ferguson had mentioned the case of a 250 K.V.A. alternator and the introduction of a condenser to remedy the power factor on the alternator. Thereby he was improving his over-all power factor, which gave a margin to enable him to make further connections, but he still had all the disadvantages of the low power factors of his motors and his mains: those were suffering in the same way after the installation of the condenser as before. It seemed to Mr. Upton that to correct the power factor effectively it was necessary to get right down to the individual induction motor. The induction motor was the apparatus producing the bad power factor, and correction should be at the point of use rather than at the point of generation. In correcting the power factor there was also the consideration—and he was looking at this from the public supply point of view rather than that of the self-contained colliery installation—that the consumers' interests be not neglected: was it right to ask the consumer to correct the power factor, or should the supply authority do it for him?

The undertaking with which Mr. Upton was connected asked the consumer to improve his power factor, and in many instances the consumer had done so and benefitted from it: but it was rather difficult to convince a consumer as to the advantages to be obtained from improvement of power factor. He looks with suspicion at an engineer who suggests such improvement in his installation, because he cannot understand the meaning of power factor. He can, however, understand the benefit to be obtained in the reduction of his K.V.A. charge and should be spoken to in terms of the reduction of K.V.A. by the installation of correction apparatus.

Continuing, Mr. Upton called attention to the number of installations on their system chiefly using small units, and the surprising improvements that had been effected by power factor correction. The figures of typical examples are as follow:

	With Correction			Without Correction				
Horse Power	K.W.	Power Factor	K.V.A.	K.W.	Power Factor	K.V.A.	Consumption per annum	Size of Condenser
44	15.24	.98	15.55	14.13	.68	20.8	28,770	13.77
26½	11.2	.88	12.75	13.2	.72	18.3	19,033	7.17
191½	75.75	.9	84.5	75.0	.7	108.0	111,151	97.

It is therefore quite clear that when charged on a K.V.A. basis it is in the interests of the consumer to get his power factor as high as possible, always taking into account that he must guard against a K.V.A. with a leading power factor exceeding the lagging K.V.A. demand. In this respect it would seem that installations of condensers should where possible be connected with the starting devices of plant, so that they can only be used during the time of running of the plant and not when the plant is standing idle. To the supply authority it means a great deal to have a high percentage of power factor. It is really very difficult to obtain 80% continuous running on any undertaking of size, and the difficulty would tend to increase as alternating current displaced direct current. With the use of rotary converters, which so many supply undertakings were thankful to have, cities such as Manchester and Birmingham with large D.C. sub-stations, were able to maintain a very high average power factor.

For many years public supply undertakings have limited the H.P. size of squirrel cage motors on their mains. Consumers have been forced into the use of slip-ring machines. It seemed paradoxical to ask for high percentage of power factor and at the same time ask for the use of slip-ring motors. The demand ought to be for high power factor and squirrel cage motors.

Mr. Ferguson had mentioned those who in putting down a motor calculated the correct H.P. for the work and then added a bit for luck. That habit seemed to be against reason, but it was very difficult to get a tradesman to understand that a 12 H.P. motor was sufficient for his job when he had in mind ambitions of adding to his plant in the future; he also wanted to be sure that he would not have to trouble his insurance people with electrical breakdowns.

Following the war period there were a great many induction motors offered for sale at various Government ammunition dumps, buildings and factories, and one could get say, a 30 H.P. motor for a very low figure: perhaps the requirement was only for 10 H.P., but in countless cases the 30 H.P. unit was installed. These must run very uneconomically and at a very low power factor.

Mr. ALEX. McPHAIL said he would like to ask Mr. Ferguson to deal with this problem: a colliery has ten coal-cutters installed. They are working at night and their load varies from 25% of the load to 25% above full load. Each coal-cutter has a 30 H.P. squirrel cage motor. What sort of machinery should be installed there to keep the power factor to the highest point, or at the best working point? The coal-cutter runs in a shift only about 2½ hours out of eight. It has a very uneven load; at one moment it may be cutting something that is extremely hard and in the next half-hour it may be cutting something that is very soft. Cases of that kind would be very hard to deal with, although perhaps it would be best to put in condensers, as Mr. Upton had said, on the motor side of the starting apparatus.

Mr. McPhail also asked why makers were adopting the principle of switching squirrel cage motors direct across the mains instead of through star-delta switches.

(At this point in the discussion Mr. Upton handed round for inspection a condenser unit having a capacity approximately of one microfarad. The unit was taken from a three-phase condenser which had been in commission continuously for ten years, and on which there had been no maintenance charges of any kind.)

Mr. KENDAL remarked that Mr. Ferguson had not spoken of repulsion induction motors. The reason why some people put in larger induction motors than was needed for the load was to get ample starting torque. The repulsion induction motor gave the starting torque but it would cost a good deal more in the first place. It would be interesting if the relative extra cost of the repulsion induction motor were compared with the loss incurred in using a larger induction motor than was necessary. It seemed to Mr. Kendall that in time it would pay to put in a repulsion induction motor and thus cut out the extra running cost of the other.

Mr. GARVEN.—It is a fact that consumers do put in larger motors than needed at the moment because they expect in course of time to develop and take more power. They are told to correct power factor by putting in static condensers, but that these must be of just the right size or the costs will be greater instead of less. Supposing the load is increased, is it easy to add to the capacity of the static condenser or would a new one be necessary?

In going over the various returns that have to be made up about a colliery it was found that coal cutters would aggregate up to about 1000 H.P., and that not anything like that amount of power was used. Perhaps the proposition would only be about a third of that power, but all the coal-cutters were running at the same time during the shift. Similarly with haulages and pumps that were running during part of the shift and they totalled about 1000 H.P. too. So the aggregate power was about 3000 H.P. installed and yet the actual running load would only be about 500 H.P. Of course, that would be made up possibly through three different shifts. The coal-cutters cut over a period of eight hours: some of the pumps were possibly working during that shift, some might be working at all times, but at any particular hour it would be found that the amount of power taken would be considerably under 50% of the rated motor capacity. A 5 H.P. pump might be pumping out of a dook against only a few feet head of water to start with, but eventually it might have 100 feet: the motor must be sufficiently large so as to be capable of meeting that contingency, and that principle applied practically all through mining work. There was necessarily a very large H.P. compared with the power consumed, which in the case of an A.C. plant leads to a very poor power factor and, as Mr. Upton had said, although that might be corrected as far as paying for the power was concerned, there were still the disadvantages inside. Possibly power factor correction should be made at several different points.

Mr. FERGUSON.—Mr. Holmes mentioned the case of a condenser being put in which was found to be too large for the load. That was due probably to the job not having been looked into thoroughly beforehand, as possibly the individual concerned might not have had any real experience in power factor work. A condenser could be disconnected: at least certain portions of it could, and thus there was provision for dealing with a future larger load. The units which Mr. Upton had exhibited were mounted on a frame: the required number of frames was left disconnected when the condenser was first installed, and for a larger future load these would be re-connected. A condenser connected for every motor in the works or colliery would be best, but that would be very expensive in first cost. A large condenser arrangement costs considerably less than, say, twenty small ones, and it became a question of costs when an installation was already in working order. The engineer putting down a plant nowadays took care to get a motor with a good power factor.

It was difficult to give a definite figure regarding the cost of a condenser equipment. Tests had to be taken over the whole installation before deciding exactly what capacity would be required. Roughly speaking a fairly general figure would be round about £4 per K.V.A. at 50 cycles.

Mention had been made of automatic control, to ensure that the condenser was not in circuit under low or no-load conditions. That question would only arise where a K.V.A. charge was made. If a consumer were charged on the sliding scale, then it would not matter whether or not the condenser was in circuit under light load or no-load because capacity did not affect the kilowatt maximum demand. The automatic feature was not generally successful. A condenser connected in a circuit had the effect of reducing the main amperage. A maximum demand trip was arranged to bring the condenser in at, say, 100 amps.: the load reaches 100 amps. and the condenser goes in; as a result the load falls below 100 amps. and the condenser trips out. The conditions are unsuitable and therefore automatic control has to be within very big limits.

With regard to the question of coal-cutters, it must be admitted that the improvement of power factor in a colliery was a very difficult proposition from the investigating engineer's point of view. The only way of arriving at a suitable size of equipment was to take a number of tests over an extended period and ascertain exactly what the power factor was at different loads. It had been mentioned that coal cutters were usually run on the back shift or night shift. The rest of the load was usually low then, so by taking the over-all power factor of the installation concerned and calculating on that load, and then taking the day, the back and night shift loads independently as a check, it was possible to design a condenser equipment in units to deal with the complete load; also by means of switching to arrange that the required capacity would be in circuit for the different shift loads. Obviously with a hard cut one hour and a soft one the next the power factor would be "all over the place," and it would be practically impossible to "spot" test it.

In a pit it was advisable to place the rectifying apparatus as near the load as possible. With regard to the repulsion induction motor, Mr. Ferguson said he could not say much about its cost, but in general it might be said that when installing a motor for power factor correction and throwing out another one, the cost of the machine discarded would be practically a dead loss unless there was other work waiting for it. Each proposition had to be considered on its own merits, and anyone laying down new plant now-a-days would take care to get machines satisfactory both from the financial and the practical point of view.

Mr. UPTON said he believed it was the practice among some supply authorities to provide their consumers with corrective apparatus on the hire purchase system, and the money saved by correction paid the yearly instalments.

Mr. FERGUSON replied that he knew of one case where that was done, but usually the manufacturer was the one to face the responsibility. If the manufacturer's representative put forward a convincing statement about the savings to be effected, the manager or director would often say, "Well, if we are going to save the whole cost in eighteen months will you gamble on it?"

The reply to the question as to whether the size of the condenser should exactly suit present requirements or not would depend on the method of charge for current. If the charge were on a K.V.A. basis the condenser can be too big; but if the charge be on the Clyde Valley method, which is an average, the consumer might make a gain one day and a loss the next. It was quite feasible to put in a condenser to allow for future requirements, but it should be so that some of the frames may be disconnected until the load increased.

WARWICKSHIRE & SOUTH STAFFS. BRANCH.

At the meeting of this Branch, which was held in the Walsall Technical College on January 17th last, Mr. F. J. Hopley the Branch President introduced Mr. C. S. Buyers, who read a paper entitled "The £ s. d. of Power Factor Correction."

Lantern illustrations punctuated the lecture, which was keenly followed by all present, and Mr. Harvey opened the discussion in which many members took part. Mr. Hopley in moving a vote of thanks said that the paper had proved of exceptional interest and was of considerably more use to the colliery electrician than the usual technical treatise of the subject. The motion was duly supported and carried unanimously. Mr. Buyers suitably responded and mentioned the compliments which he had received from the Branch by the excellent attendance of its members.

The £ s. d. of Power Factor Correction.

C. S. BUYERS.

There has been in the past a number of papers read before this Association on power factor correction but these papers have, in the main, dealt with descriptions of apparatus used for this correction and with their application to mining work. It is therefore proposed in this paper to deal more particularly with the economic aspect of the subject, and in the present depressed state of the coal mining industry the question of economics deserves close consideration.

It has been rightly stated that the man who makes two blades of grass grow where previously only one grew is a benefactor of mankind, and it is the author's submission that if by efficient drives and by power factor correction a colliery electrical engineer makes two amperes do the work which previously required three amperes then he also is a benefactor not only to his own particular sphere of work but to the mining industry as a whole.

It must be recognised first of all that any electrical apparatus installed for power factor correction purposes is installed purely for economic reasons. Take, for example, the autosynchronous motor which is used to a considerable extent in collieries for driving fans and air compressers and also to a certain extent for driving pumps and haulages: it is not installed for any particular property other than that its power factor is under control and may be used for correction purposes. A slip-ring induction motor is equally efficient, robust and reliable and some 20% to 40% cheaper in first cost but, under certain conditions which apply to many collieries, it is wrong economically to instal a large induction motor in preference to a synchronous motor which will not only drive the load required but will improve the overall power factor and efficiency of the plant.

Two cases arise for consideration: Firstly, the case of the colliery which generates its own A.C. power supply and, secondly, the case where power is purchased in bulk from an external source of supply. In general terms it may be said that it pays the small or medium sized colliery up to say 1000 K.W. capacity to purchase power, provided a suitable supply is available, whereas the large colliery group can undoubtedly generate electric energy more economically than the majority of supply companies can afford to sell it under present conditions.

Effect of Power Factor Correction on Generating Plant at Colliery.

Assume a generating plant consisting of two 1000 K.V.A. three-phase 3000 volt 50 cycle turbo-altenators. It is the usual practice to have the alternators designed to deal with a load at 0.8 P.F. so that the machines in question would be 800 K.W. each. The load will possibly consist of main fan, haulages, compressors, pumps and perhaps coal-cutters, also surface workshops and screening plant. The motors above 100 H.P. are usually wound to take 3000 volts, but the smaller machines and lighting load will be supplied through step-down transformers at a pressure of 500 volts for power and 110 volts for lighting. With a load of this description it is not unusual to find that the overall power factor averages 0.65 to 0.7 lagging and it may be necessary to run both generating sets in parallel to deal with the K.V.A. demand when the actual K.W. demand is within the capacity of one set.

By replacing the fan or compressor motor by an autosynchronous machine working at a leading power factor, and thus raising the power station bus-bar power factor to 0.8, one generating set will carry the load and a saving in fuel consumption of 5% to 10% will be obtained.

A case was reported in the Proceedings of this Association some years ago (Vol. VI., page 77) where three steam alternators had to be run continuously at nearly full load current at a power factor of 0.65, but after the installation of a synchronous motor the current was reduced from 1150 amps. to 850 amps. and the power factor was raised to 0.9. This permitted one alternator to be shut down and kept as a standby. As the other two generating sets were able to be utilised under approximately full load conditions their steam consumption was improved and it was found possible to shut down one boiler out of eight.

Another case was stated in the "Electrical News" (Vol. 83, page 127) where the introduction of a static condenser effected the shutting down of a 200 K.W. set and a boiler, the other set alone being able to carry the load, and the saving effected very soon compensated for the initial outlay.

If an alternator is working at a power factor lower than that for which it is designed the useful output is reduced in proportion, thus a 1000 K.V.A. alternator designed for 0.8 P.F. has an output of 800 K.W., but if the power factor is 0.6, the output is reduced to 600 K.W. the actual current being the same in both cases. Even when working at 600 K.W. output at 0.6 P.F., the exciter will be overloaded to maintain correct voltage due to the demagnetising effect of the lagging current, and in many cases the output of the set will be limited by the exciter capacity.

The efficiency of the alternator alone, apart from the prime mover, will be on an average 2½% lower when carrying full load current at 0.6 P.F. if designed for a power factor of 0.8.

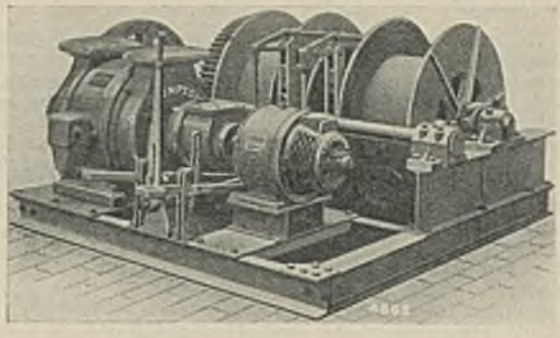

Fig. 1.—A 50 B.H.P. Autosynchronous Motor driving an Underground Haulage.

Apart from efficiency the voltage regulation is adversely affected by low P.F. lagging. If designed for 20% regulation at 0.8 P.F. the regulation (or rise in pressure when full load is thrown off) will be, in the case of a 500 K.W. alternator, increased to 25% at 0.6 P.F. Poor regulation when the load conditions are of a fluctuating nature is a serious disadvantage as the voltage falls at times of peak load and heavier currents flow throughout the system necessitating the setting of overload trip relays at higher values than desirable.

Where low power factor and poor voltage regulation exist it will usually be found that cables and switchgear run warmer than is desirable and the overall efficiency of the plant is much reduced.

It is of course possible to design the alternator originally to have good voltage regulation, but this increases the size and cost. For instance, a 500 K.W. alternator running at 375 r.p.m. designed for 15% regulation at 0.8 P.F. would cost approximately 10% more than one for say 28% regulation at the same power factor.

Supply Not Generated at Colliery.

If the electric supply is obtained from an external source such as a Power Company the question of power factor assumes, as a rule, an even greater importance as in the majority of cases the price tariff is based on K.V.A. maximum demand or has a clause providing for a penalty or bonus according to the average power factor.

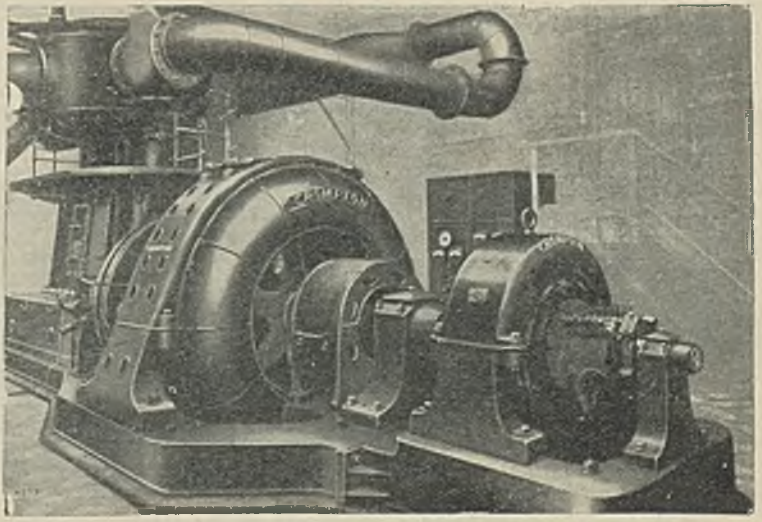

Fig. 2.—An 800 B.H.P. Autosynchronous Motor driving a Compressor at a Colliery.

Transformers.

External supply is usually delivered at high tension or extra high tension and requires to be transformed down to a suitable pressure. A transformer is rated in K.V.A. and its output capacity is K.W. is directly proportional to the average power factor of the load. For example, a 1000 K.V.A. transformer would supply a load of 800 K.W. at 0.8 P.F., but the output would require to be reduced to 650 K.W. if the power factor was as low as 0.65, and as the losses remain the same the true efficiency is slightly lower. The voltage regulation of a transformer is affected by the power factor of the load but not nearly to the same extent as in the case of an alternator. The normal regulation of a 1000 K.V.A. three-phase transformer 11,000/500 volts would be 1% at unity P.F., 3% at 0.8, and 4½% at 0.6 P.F.

The chief economic point of interest in transformers is therefore their prime cost which is proportional to the K.V.A. capacity and thus to the P.F. of the load. If a transformer is already fully loaded and extra capacity is required for extensions, instead of installing an additional transformer to work in parallel with the existing one, the extra capacity may be obtained by improving the power factor of the load.

Losses in Cables.

The losses in the distribution cables are the same whether the power is generated at the colliery or purchased in bulk. These losses, usually known as the C^2R losses, vary inversely as the square of the power factor. With a cable of given cross sectional area the transmission loss for equal amounts of energy transmitted is twice as great for 0.7 power factor as it is for unity. At 0.5 P.F. the transmission loss would be four times as great compared with unity. It is evident from these figures that it is desirable to do the correction at the far end of the cable where the load is or as near the centre of gravity of the load as possible so that the cables are relieved of idle currents.

If correctional plant is placed in proximity to the main bus-bars on the surface, the cables and transformers underground receive no benefit and require to be of greater capacity than if the correction be carried out close to the plant which is causing the low power factor.

Autosynchronous motors having a leading power factor have been supplied to collieries for driving underground haulages and pumps. An endless haulage being a fairly constant load is more suitable than a main and tail, but it will be found that if a number of autosynchronous motors are installed on drives where there is constant starting and stopping, the diversity factor will be such that the overall power factor is raised.

Tariffs.

The basing of power load tariffs on power factor is becoming the usual practice and will undoubtedly become almost universal in this country in a few years' time. It is unfair to the consumer to charge A.C. supply on a K.W. maximum demand or flat rate basis without a power factor clause, as this means that the consumer whose P.F. is 0.9 is being penalised for the benefit of the consumer whose P.F. is 0.6, and it is the author's submission that a power supply company has no moral right to make the inefficient consumer benefit at the expense of the consumer whose plant is run more efficiently.

The question of tariffs at the present time is somewhat involved as there is a large number of different tariffs and it is open to any supply authority to make its own tariff irrespective of what is being done in other industrial areas of a similar character.

In general, tariffs based on power factor may be divided into three classes:—

(*a*) A special rebate being a percentage of the total monthly or quarterly account for improvement of power factor. For example, Birmingham Corporation allow a rebate of 3% if the average power factor exceeds 0.85 lagging and 5% where it exceeds 0.9. Salford have a sliding scale varying from a bonus of 8% for 0.95 P.F. to a penalty of 7% for 0.6 P.F.

(*b*) A tariff consisting of two parts, viz., a fixed charge per month or quarter on the maximum K.V.A. demand plus a flat rate per unit consumed. On an average this is about £5 10s. 0d. per K.V.A. per annum plus a varying figure of 0.25 pence to 0.5 pence per unit, depending on the total number consumed in stated period.

(*c*) A tariff consisting of two parts, viz., a fixed charge per month or quarter on the maximum K.W. demand plus a flat rate per unit consumed. The fixed charge is based on a standard power factor of 0.8 or 0.75 and increased or decreased in inverse proportion to the actual power factor. For example, the Clyde Valley Power Co. base their rate on a power factor of 0.8 and if a consumer maintains his average power factor at unity he will receive a rebate of 20% on the maximum demand charge, which varies from £10 to £6 per K.W. per annum according to load. If the average power factor is below 0.8 a proportionate penalty is charged.

The tariff (b) appears to be, for usual conditions of supply, the most popular method of charging as it is simple and equitable to both supplier and consumer.

As low power factor increases the Supply Company's standing charge it would appear that for large consumers the most equitable tariff is one based on maximum K.V.A. demand plus a flat rate per unit.

Methods of Metering Power Factor.

There is a number of methods of metering in use by which the power factor of the load is taken into consideration. The K.V.A. maximum demand may be read direct from a K.V.A. demand meter. This has the advantage to the consumer that the power factor at time of maximum demand is usually better than the average power factor of the installation. Another method adopted is to instal a K.W. demand indicator, also sine and cosine meters, from which the average power factor can be calculated. The sine meter reads the "Wattless" and the cosine meter the useful or energy units.

Certain supply authorities instal two single phase watthour-meters in addition to a maximum demand indicator.

Each system of metering has its peculiar advantages and disadvantages, and it is to be hoped that systems of metering will gradually be unified throughout the country in the interests of industry in general.

Saving by Power Factor Correction.

The percentage saving which will result from improvement of power factor varies very considerably as it depends on the existing conditions of load and on the terms of the price tariff. The most favourable conditions for making the maximum saving are present when:—

(*a*) The existing P.F. is low.

(*b*) The necessity has arisen for additional motor or motors of sufficient size to be suitable to be of autosynchronous type and where the duty entails long running hours.

(*c*) The tariff is based on a high maximum K.V.A. demand charge plus a fraction of a penny per unit used.

Take for example a load having a maximum demand of 500 K.W. three-phase 50 cycles at 0.7 P.F. lagging, which is equal to 714 K.V.A. Assume the tariff to be £6 per K.V.A. maximum demand plus 0.35d. per unit, and the annual consumption to be 1,000,000 units (load factor 23%). An additional motor of 200 B.H.P., 3000 volts, 500 r.p.m. is required. If this is an induction motor it will raise the P.F. at maximum load to 0.74, and will consume say 300,000 units per annum.

Condition with Induction Motor.

Max. demand 663 K.W. at 0.74 P.F.	895 K.V.A.
895 K.V.A. at £6	£5,370
1,300,000 units at 0.35d.	£1,896
Interest, Depreciation, etc., on cost of induction motor and control gear, 15% on £500 ...	£75
Total	£7,341

Condition with Autosynchronous Motor at 0.65 leading P.F.

Now consider the case where a 200 B.H.P. autosynchronous motor is installed such that the P.F. is raised to 0.9.

Max. demand 666 K.W. at 0.9 P.F.	740 K.V.A.
740 K.V.A. at £6	£4,440
1,307,500 units at 0.35d.	£1,907
Interest, Depreciation, etc., on autosynchronous motor and control gear, 15% on £700	£105
Total	£6,452

The autosynchronous motor at 0.65 leading P.F. will be 2½% less efficient at three-quarter load than the induction motor, the units are therefore increased by 7500.

The annual saving is £7,341 — £6,452 = £889 or 12%.

The extra cost of autosynchronous motor over induction motor cost would be £200, which would be saved out of the first quarter's account.

Condition with Autosynchronous Motor at 0.5 leading P.F.

It may be of interest to consider the effect of raising the P.F. from 0.7 t. 0.95 lagging.

Maximum demand 670 K.W. at .95 P.F.	705 K.V.A.
705 K.V.A. at £6	£4,230
1,315,000 units at 0.35d.	£1,918
Interest, Depreciation, etc., on autosynchronous motor and control gear, 15% on £800	£120
Total	£6,268

The total cost per annum of the installation when the P.F. was raised to 0.9 was £6,452, whereas when raised to 0.95 P.F. the cost is £6,268, being a reduction of £184. The autosynchronous motor working at 0.5 leading would cost £100 more than a similar machine designed for 0.65 leading P.F. In this case it would accordingly be the most economical proposition to correct up to 0.95 lagging, the saving being 14%. It will be noticed that the saving effected between 0.9 P.F. and 0.95 P.F. is not very considerable, only 2%, and 0.95 may be taken as the economic limit.

To raise the P.F. from 0.95 to unity would require an addition of 230 wattless leading K.V.A., and the increased capital and running charges would considerably outweigh the small reduction in K.V.A. maximum demand charge, with the result that the total costs per annum would be greater to correct to unity than to 0.95 lagging. It may be stated, therefore, that excepting in special circumstances it is not an economical proposition to raise the overall power factor above 0.95 lagging. This will be better realised when it is remembered that the leading wattless component required to raise the P.F. of a given K.W. load from 0.95 to 1.0 is practically the same as to raise the P.F. from 0.8 to 0.95.

Condition with Induction Motor and 275 K.V.A. Static Condenser.

A case to be considered is the economic position if the induction motor is installed together with a static condenser to raise the overall P.F. to 0.9.

Max. demand 667 K.W. at 0.9 P.F.	741 K.V.A.
741 K.V.A. at £6	£4,446
1,310,000 units at .35d.	£1,910
Interest, Depreciation, etc., on cost of induction motor and control gear, 15% on £500 ...	£75
Ditto. on cost of 275 K.V.A. Static Condenser, 15% on £750	£112
Total	£6,543
Total cost of induction motor plus condenser ...	£1,250
„ „ autosynchronous motor at .65 P.F. leading	£700
Saving in capital cost by autosynchronous motor	£550
Annual cost with induction motor plus condenser	£6,543
„ „ autosynchronous motor at .65 P.F. leading	£6,452
Annual saving in running costs with autosynchronous motor	£91

Condition with Induction Motor and 370 K.V.A. Static Condenser.

Consider raising the P.F. to 0.95 by Static Condenser.

Max. demand 669 K.W. at 0.95 P.F.	704 K.V.A.
704 K.V.A. at £6	£4,224
1,314,000 units at .35d.	£1,916
Interest, Depreciation, etc., on cost of induction motor and control gear, 15% on £500 ...	£75
Ditto. on cost of 370 K.V.A. Condenser, 15% on £1,000	£150
Total	£6,365
Total cost of induction motor plus condenser ...	£1,500
„ „ autosynchronous motor at 0.5 P.F. leading	£800
Saving in capital cost by autosynchronous motor	£700
Annual cost with induction motor plus condenser	£6,365
„ „ autosynchronous motor at 0.5 P.F. leading	£6,268
Annual saving in running costs with autosynchronous motor	£97

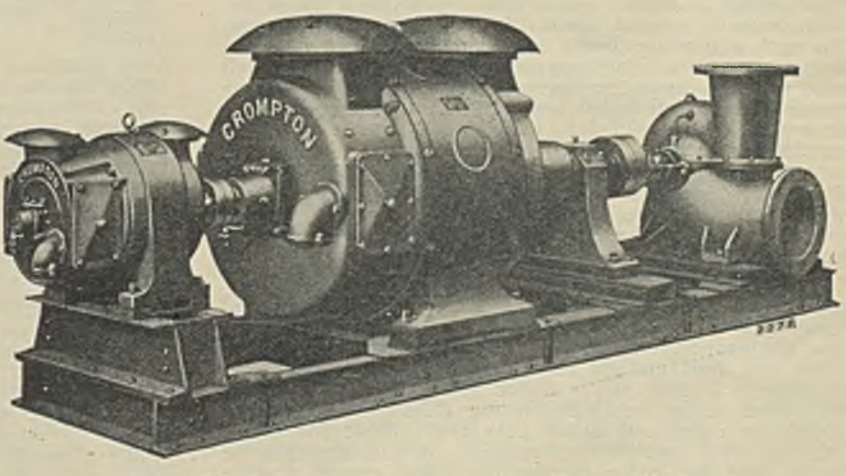

Fig. 3.—*A* 120 *B.H.P. Autosynchronous Motor driving a Centrifugal Pump.*

These two examples show that under the conditions taken the static condenser would not be the most economical method to adopt. If the figures be examined it will be noticed that even if the induction motor were existing it would be more economical to replace it by the autosynchronous type than to instal a large static condenser. The static condenser, if adopted, would be used to best advantage if split into smaller units, these being used in positions underground where the wattless currents in transformers and cables could be reduced with advantage.

Plant for Improving Power Factor.

A short description of the plant used at collieries for improving the power factor may be of service to those dealing with this problem. This plant may be divided broadly into three classes:—

(*a*) Synchronous or autosynchronous motors.
(*b*) Phase advancers.
(*c*) Static condensers.

(a) Synchronous motors may be either salient pole or cylindrical rotor type. The salient pole machine has a starting torque of only 35% to 40% of full load torque but may be used for driving air compressors or motor generator sets. It is started up by an autotransformer starter in a similar manner to a squirrel cage motor and takes approximately 1½ times full load current at starting.

The cylindrical rotor type generally known as the autosynchronous or synchronous induction motor is used to a much greater extent owing to the fact that it will start against 2½ times full load torque and can be designed to synchronise automatically against 1⅓ times full load torque. It can be designed equally well for low speeeds such as 150 r.p.m. or high speeds up to 1500 r.p.m. on 50 cycles, consequently it is entirely suitable for driving, main fans, compressors, screening plant, endless haulages and pumps.

For winding plant the slip-ring induction motor is more suitable, but where a motor generator is required for a winder having Ward Leonard control the motor may be of the synchronous type. In such cases it is desirable that the motor be designed to do a considerable amount of correction and have a power factor of say 0.8 leading in order that the pull-out torque will not be less than 200% of full load torque. A normal unity power factor autosynchronous motor designed to drive an air compressor would have a pull-out torque of approximately 140% of full load. As air compressors are not subjected to heavy overloads this is quite satisfactory.

If pulled out of step by overload an autosynchronous motor will continue to run as an overloaded induction motor and lock again into synchronism when the load becomes normal again. It is undesirable, however, to work a machine under such conditions owing to the heavy current which flows when the machine is pulled out of step, and the correct procedure where heavy overloads are anticipated is to have the machine designed to work at 0.8 or 0.7 P.F. leading and thus ensure good overload capacity.

When a synchronous motor is being used partly for P.F. correction purposes, the most economical figure is 0.7 P.F. leading, because at that figure the K.W. energy component and the wattless leading component are equal.

(b) The phase advancer is, as a rule, a small separately driven machine provided with a commutator and connected to the slip-rings of an induction motor. It has the property of injecting a leading E.M.F. into the rotor and thus making the stator or line current attain unity or a leading power factor. A phase advancer may be added to an existing slip-ring induction motor provided the rings and brush gear are suitable for carrying the rotor current continuously. It will generally be found that the rotor current must not exceed a value sufficient to raise the stator power factor to unity, otherwise overheating of the rotor winding will occur.

An induction motor can, of course, be designed originally in conjunction with a phase advancer to draw a leading current, but in such case the autosynchronous motor with D.C. exciter has certain advantages and is more frequently adopted.

(c) The static condenser. The most economical voltage for static condensers has been found to be 600 volts, although by placing the elements in series it is possible to use them direct across 3000 volts. When the voltage is 420 an auto-transformer is provided as the combination of transformer and 600 volt condenser is cheaper and less bulky than a 420 volt condenser. Static condensers have been used in collieries for a number of years and there is a field for them in cases where the induction plant is already existing and where it is undesirable to replace existing machines by autosynchronous type.

Conclusion.

In conclusion the author would draw attention to the fact that power factor correcting devices are not used to the extent they should be as it is not sufficiently realised that in many cases the necessary capital outlay would result in very good interest on capital. An eminent engineer recently stated in London that he had estimated that if the power factor was improved throughout the country by only 5%, the saving in loss on energy, etc., would amount to no less than £150,000 per annum.

Discussion.

Mr. G. M. HARVEY.—The author has treated a subject which is in danger of being done to death in "papers," but he had served the fare in a novel and refreshing way, and given a vast amount of interesting data impossible to assimilate at one sitting. With regard to the broad question as to the necessity for, or the economy of, power factor correction, it has been proved beyond question that by providing motors of a rating commensurate with the load they are required to carry, the power factor of a colliery system may be maintained without difficulty at 0.8 to 0.85. The whole of the trouble lies in persistently over-estimating the load requirements in the future, so as to be "on the safe side," with the result that the motors are running for a large proportion of the time at something like quarter load. With a little foresight, provision could be made for substituting motors of progressively higher rating as the load increased, at a cost much lower than that of the requisite plant for power factor correction. It was to be hoped that when the paper is printed in "The Mining Electrical Engineer" the author would include worked out examples on each of the methods of charging which he had described, for purposes of comparison.

It seemed to Mr. Harvey questionable whether a reduction in the size of cable required would justify the installation of correcting apparatus in-bye. The author's allowance of 15% for interest and depreciation only allowed a life of ten years for the plant, which seemed a little unreasonable. The figures given for the cost of static condensers seemed very high, and presumably would be higher still if the condensers were split up into smaller units, connected to groups of motors. Does a static condenser give a constant correction over a wide range of loads?

Mr. HENRY JOSEPH said that, in his opinion, a tariff based on K.V.A. of maximum demand was the only reasonable one. It was the only method of charging which offered an adequate inducement to the consumer to improve his power factor. He had known several cases where the cost of condensers was paid for in about 14 months owing to the reduction of the maximum demand where consumers had paid on this basis. Where the plant was already existing and no large extensions were contemplated the case for static condensers was very strong.

He found it difficult to follow the author when he gave the figure of £500 for an induction motor and £750 for static condensers as against £700 for a rotary condenser, from which it was deduced that it was more economical to scrap induction motors and put in rotary condensers than to instal static condensers with existing induction motors. A very economical plan was to instal static condensers in small units connected across the stators of a few of the larger motors. That would avoid all switchgear, and as these motors were shut down the capacity was automatically reduced.

An ideal place for power factor correction by rotary condensers was at such steady drives as fans or compressors. Mr. Harvey had advocated the grading of haulage motors, but that was always difficult, and the case was adequately met by installing large enough motors for the ultimate load, and correcting the low power factor resulting from underloading them by means of static condensers. It was better, said Mr. Joseph, to aim at standardisation rather than changing motors with increasing lengths of roads.

Mr. C. M. BROWN.—The author claimed a very wide field for the application of the autosynchronous motor, and while it may have been applied successfully to underground haulage duty in certain isolated cases, usually it must give way to the more flexible induction motor-condenser combination. However reliable the synchronous motor, it must be regarded as an additional complication only to be employed in the conditions usually associated with underground haulage, when other means of achieving the object were not available. If, for example, the steady load provided by an adjacent pump was available then, it appeared to Mr. Brown, that the haulage should be left to a plain induction motor, and sufficient correction provided at the pump to compensate for the lagging power factor of the haulage.

As a general policy it would seem that where the purpose of the correction was to provide for improvement of the power factor of the system in excess of the requirements of the point of application of the synchronous motor, a steady load at that point was desirable, and that where the correction was employed in association with a fluctuating load, its extent should be limited to the requirements of the load at that point.

Mr. I. T. DIXON put a question: Where there are a number of motors, none of large size, would it not be preferable to instal one condenser for the total load rather than to put in a synchronous motor specially for power factor improvement in a case when buying current on a K.V.A. basis?

Mr. E. W. WALKER.—The auto-synchronous motor seemed to be a fair amount dearer than the ordinary slip ring motor, and it would appear that a large portion of the extra cost was due to the fact that a combination bedplate to carry the motor and direct coupled exciter was always supplied. Would it not be possible to use an overhung exciter in the small sizes, the field magnet of the exciter to be carried on a bracket fixed or cast on the motor end-shield? Alternatively, would a chain or belt driven exciter be satisfactory? In the latter case it would save the bedplate and also a higher speed exciter could be used which would cheapen the equipment considerably.

With regard to compensated induction motors, of which a number are on the market, these appeared to have two disadvantages. The first was that they involve the commutation of alternating current, and anyone with experience of this is not inclined to have this type of machine if it can be avoided. The commutation of alternating current was fairly satisfactory so long as the commutator was kept perfectly clean, but in many cases, particularly in the Midlands, trouble could be anticipated almost from the start from dirt and damp.

The other disadvantage was that the speed varied considerably from no-load to full-load, and whilst it was true that the ordinary induction motor had this characteristic, he believed that the compensated induction motor had it to a much greater degree and may not be satisfactory for all purposes.

Mr. C. S. BUYERS (in reply).—Mr. Harvey has correctly indicated the cause of low power factor in collieries where it exists, namely, the installation of motors of greater horse-power than necessary to allow a margin for future requirements. The question of installing correcting apparatus in-bye was a debatable one, and unless when the conditions underground made it a favourable proposition, it was better to carry out the correction on the surface.

With regard to the allowance of 15% for interest, depreciation, etc., the figure was made up of 5% interest, 5% depreciation, and 5% to cover such items as renewals, insurance, supervision, etc. The cost figures for static condensers were obtained from prices ruling at the end of 1928 when the paper was written. If split into smaller units the cost would undoubtedly be greater.

A static condenser draws a constant leading current from the system to which it is connected no matter what the inductive load happens to be, and the overall or average power factor would be the resultant of the vectorial sum of the individual power factors of motors and condensers connected to the system.

Mr. Harvey had asked for worked out examples on each method of charging. Examples might, however, be misleading as tariffs vary so greatly that it would be difficult to strike an average figure for each method. Where a supply authority offers alternative methods of charging, the matter should receive very careful consideration before a decision was made on the best tariff to adopt. For example, one Corporation offers alternatives to consumers having a demand above 300 K.V.A.:

(a) Fixed charge of £7 per K.V.A. per annum plus 0.3d. per unit.

(b) Fixed charge of £6 per K.V.A. per annum plus 0.4d. per unit.

Consider the example given in the paper of auto-synchronous motor working at 0.65 leading P.F. to raise P.F. from 0.7 to 0.9 lagging:—

Tariff (a)—	
740 K.V.A. at £7	£5,180
1,307,500 units at 0.3d.	£1,634
Total cost of energy	£6,814
Tariff (b)—	
740 K.V.A. at £6	£4,440
1,307,500 units at 0.4d.	£2,180
Total cost of energy	£6,620

It will be seen that Tariff (b) shows a considerable saving under this condition.

Other conditions could be worked out for each tariff until the most economical P.F. at which the installation should be worked is arrived at.

Mr. Joseph found some difficulty in following why in certain circumstances it might be more economical to replace an existing induction motor by means of an auto-synchronous motor rather than add a static condenser. In one example given in the paper the total cost of auto-synchronous motor was £700 against £750 for static condenser, and in the other case £800 against £1,000, and in both cases the efficiency of the auto-synchronous motor was slightly higher than the combined efficiency of induction motor plus static condenser.

It was, of course, possible to connect a static condenser across the stator terminals of an induction motor, but if the motor were wound for 420 volts or 3000 volts, a transformer would become a necessary adjunct to the condenser, thus increasing the complication. It was not altogether an advantage to have the condenser shut down when the motor was stopped, as for reasons of economy it was best to have the condenser in circuit during the whole time the colliery is working. With the average colliery there was not much likelihood of the condenser, if left in circuit continuously, overbalancing the inductive load and causing the bus-bar power factor to assume a leading value.

Mr. Brown appeared to favour the induction motor-static condenser combination for underground haulages where no steady load, which could conveniently be driven by a synchronous motor, was available. The use of auto-synchronous motors for driving haulages was very limited, as a fan, compressor or pump load was usually available, and was undoubtedly more suitable where P.F. correction was desired. A point to be kept in mind was that when the induction motor static condenser combination was used for correcting the P.F., the static condenser should be of sufficient capacity to supply corrective current for the whole plant, whereas when a synchronous motor was installed, the plant to be corrected was naturally one induction motor less.

Mr. Dixon had raised the question of the advisability of installing one static condenser where the motors installed were of small size. That undoubtedly was the condition where the static condenser became a favourable proposition. On the other hand it should be remembered that auto-synchronous motors could be made quite satisfactorily in sizes as small as 30 B.H.P., and there were a large number in use in sizes below 100 B.H.P. Those comparatively small sizes were installed, however, more largely in factories than in the underground workings of collieries.

Mr. E. W. Walker asked a question about the bed-plate usually supplied with auto-synchronous motor to carry the exciter. For sizes under 100 B.H.P. the extra cost of bed-plate widens the difference in cost between the auto-synchronous type and induction type of motor, and one firm, viz., Messrs. Crompton Parkinson, if not more, has recently placed on the market auto-synchronous motors having overhung exciters and no bed-plate. Chain driven exciters were only used when the end space available was extremely limited, as the difference in cost between a chain driven exciter and a direct-coupled exciter plus bedplate was not as a rule sufficiently attractive to offset the added complication. With regard to the compensated induction motor, that machine has a commutator and slip-rings and double windings on the rotor: features which limited its use underground to situations where total enclosure of the brushgear were not essential, and where the working conditions were favourable.

WEST OF SCOTLAND BRANCH.

Earthing.

JOHN WISHART.

(*Paper read 20th March,* 1929).

A Motto.

Effective "Earthing" is the proved safeguard against personal accident by electric shock.

General.

This paper on the all important question of earthing has been compiled more from a practical than a technical point of view. There is much that is slip-shod and negligent in regard to the arrangement of adequate protective earthing. Here is a quotation from an article in our official Journal *The Mining Electrical Engineer* regarding earthing: "Absurd is it merely to bury an earth-plate, link up motor frames and cable sheaths thereto, and rest content in a fool's paradise of electrical security. In effect an earthing system is very similar to a live system. The common centres (corresponding to the power house or sub-stations of the live system) are the earth plates from which the sub-divided earthwork radiates. It would in some cases appear to be extremely difficult to ensure an altogether safe earthing system for an extensive colliery property, but it is always possible to plan the system in accordance with established rules of electrical circuit design, supplemented by intelligent test and experiment to meet the peculiar local conditions. An earth circuit may be 'abused' just as may a live electrical circuit. Furthermore, an earthing system properly designed and installed may, nay surely will, deteriorate with the passing of time, with neglect and with changes or extensions of the live electrical system, which again brings us back to the use of electrical recording instruments."

A leading question is: "Who are responsible for the carrying out of efficient earthing?" The correct answer is, "None other than the practical electricians themselves." Specifications may give them their necessary data and instructions, but it cannot give them clean joints, tight connections, care and practical efficiency. They must do their part and do it thoroughly.

Looking over the Electrical Inspector of Mines Reports from 1923 to 1927 inclusive, it is found that, approximately, out of 47 fatal accidents reported 15 were positively due to bad earthing, and from 1922 to 1927 inclusive approximately 26 were due to bad earthing out of 327 non-fatal accidents reported.

TABLE OF FATAL ACCIDENTS.

Date.	*Reported.*	*Due to Bad Earthing.*
1923	12	3
1924	13	6
1925	8	3
1926	4	2
1927	10	1
Total	47	15

TABLE OF NON-FATAL ACCIDENTS.

Date.	*Reported.*	*Due to Bad Earthing.*
1922	58	5
1923	70	6
1924	57	4
1925	52	5
1926	37	0
1927	53	6
Total	327	26

It will be useful now to review a few remarks made by Mr. Horsley (H.M. Electrical Inspector of Mines) on some of the above accidents.

Concerning an Unearthed Neutral.

(*Vide* Report 1925, page 17): "There are still some engineers who argue that there is less danger of a fatal shock from a three-phase system if the neutral point is insulated. It may be worth while to point out that during the last three years, out of a total of 28 fatal electric shock accidents on three-phase systems the neutral point was insulated in 19 instances."

(*Vide* Report 1923, page 9): "At the present day it is generally admitted that the balance of advantage is substantially on the side of earthing the neutral point, and it is to be hoped that mining interests will voluntarily come into line with the best present-day practice in this respect."

(*Vide* Report 1924, page 7): In this fatal accident an earth wire had been insufficiently fixed and pulled out of its terminal. Mr. Horsley in his report says that "It points to a need for more frequent expert examination, supplemented by tests, of such appliances which are unavoidably subjected to rough usage."

Concerning the Earthing Pin on a Coal-Cutter.

(*Vide* Report 1924, page 8): The plug box on a machine had been repaired at some time and a home-made "earthing pin" had been fashioned in such a manner that the shoulder of this pin would not pass through the hole in the cover plate of the plug box. The effect was that it was not possible to screw this pin sufficiently far in to apply pressure to the face of the plug casing in accordance with the original purpose of the device. Even when the cover plate was removed it was impossible to screw the pin home so as to bring the shoulder against the plug. The circumstances well illustrate the need for thorough and informed examination and test of such an important safety feature as the earthing contact, before putting such apparatus into use and regularly thereafter.

Concerns a Grave Neglect of Duty.

(*Vide* Report 1924, page 14): This fatal accident was caused through the armouring of the cable not being properly attached to a switch case and a supplementary bonding clamp was found to be loose on the cable, so that both means for ensuring the earthing of the switch case were ineffective.

(*Vide* Report 1926, Item 2, page 10): A quarry labourer received a fatal shock from an iron pipe coupled to a small D.C. electrically driven compressor. This accident was due entirely to neglect of the elementary precaution of earthing the electrical apparatus.

Many more instances of fatal accidents due to defective earthing could readily be quoted. The examples given will suffice to show the extreme importance of sound and efficient earthing.

Earthing for Open Wiring Systems.

In reviewing an earthing system one has to start at the core, the main earthplates, work out to the testing links, and on to the system, be it open wiring or armoured as the case may be.

In factories, mills, or large engineering works, where the official regulations are not so rigid as for mines, most of the wiring to motors and switchgear is run on V.I.R. on porcelain cleats, with no common earthwire discharging leakage to a main earthplate. The practice in the past was local earthing to water pipes, iron structures, or to a pipe driven into the ground. Under this system the iron structures, instead of dissipating a charge often became alive. The local earth pipes, many of which were not in suitable soil, also failed, thus causing great danger. It was also impossible to test the amount of leakage to earth at any time. In this advanced age one can hardly credit that such a method should continue, but there are many places where it does exist. The author proposes therefore to advance a few suggestions which he believes could be carried out efficiently and cheaply to modernise this precarious system of earthing.

First, two earthplates (types and sizes of which will be referred to later) should be sunk near the power house or main sub-station at not less than 20 yards apart, and surrounded with good quality coke. In the event of the soil being of clay of a dry nature a supply of water would require to be frequently applied. A

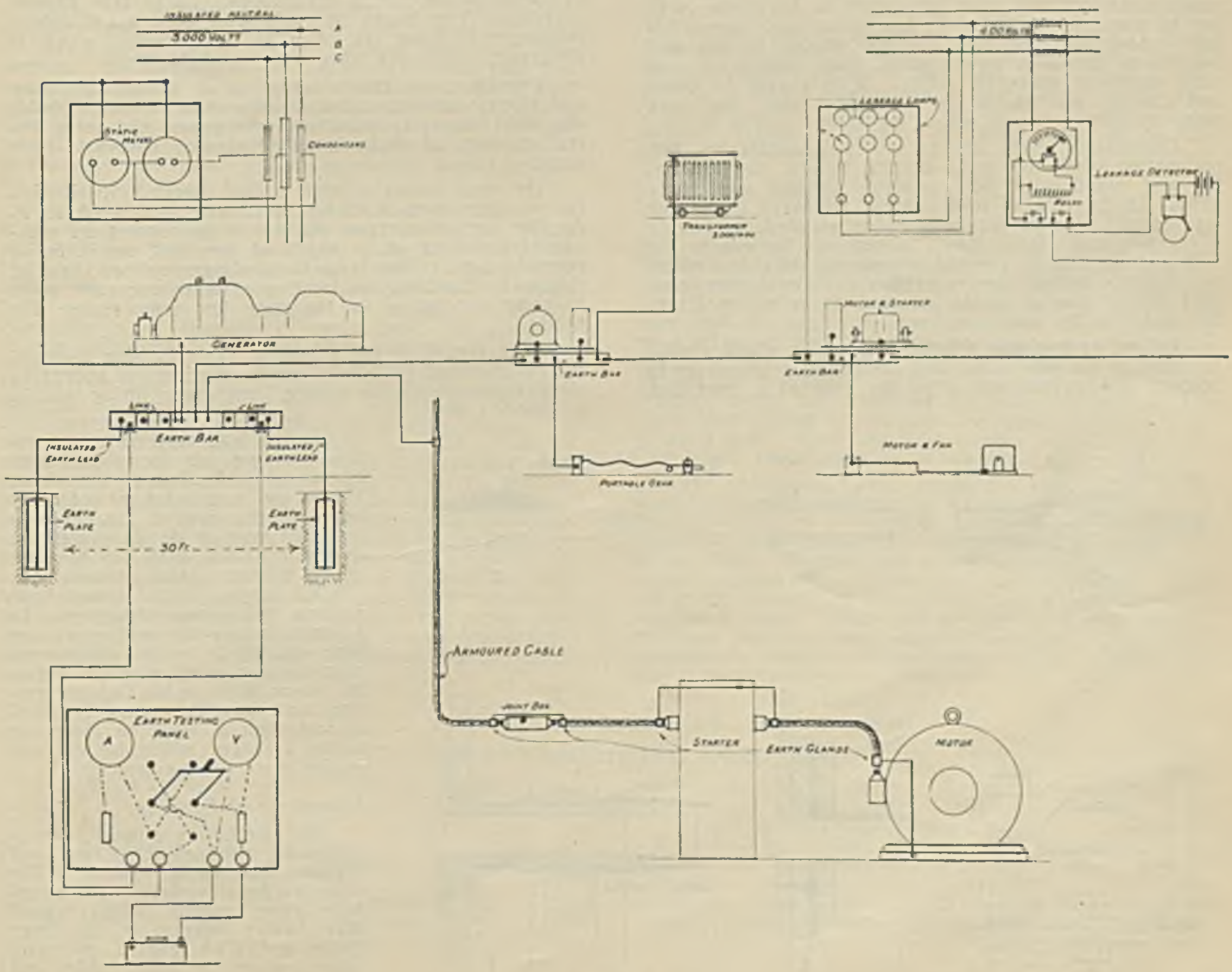

Fig. 1.

copper strand wire or copper strip of sufficient cross sectional area should be taken from each of the earthplates, connected to the copper bars on the same, and run on insulators to a common earth bar in the power house. From the earth bar a copper cable or bar would be connected to the main power plant, also copper stranded wires, which need not necessarily be run on insulators, could be carried throughout the system to the different places of distribution. To curtail expense scrap copper V.I.R. cable of sufficient length and section, minus unsweated joints, could be utilised, connecting each individual motor, switchgear, or fuse box to the same and thus linking up the whole system to a common earth return.

A method of visible indication in the power house should be adopted (where medium pressure) by means of a set of 16 candle power carbon lamps suitably connected, and placed in a prominent position to attract the attendant's attention should a fault develop. An earth detector recording meter could also be connected, should it be deemed advisable to log the amount of leakage. Fig. 1 shows the lay-out of an earth scheme of this character.

Bonding of Armoured Systems.

All collieries have, or should have, now an armoured system wherein all wiring is under metallic covering, and all cables armoured. Starting at the earth plates, again carry out the same procedure to the main earth bar as was referred to in the last paragraph. From this bar, copper stranded cable or bar should be run and bonded to the main power plant, main switchgear, and main outgoing armoured cables. With regard to cones and clamps, and glands for armoured cable, there are many designs, a few of which are shown in Fig. 2.

Present-day earth glands are fairly substantial but, no matter what the make or the design, the armouring and gland must be thoroughly cleaned and firmly fixed. In the case of lead covered armoured cables the lead should also be firmly fixed or glanded, preferably by a split lead cone. Many do not now believe in the ball jointing of lead covered armoured cables, but where possible the author always prefers it. Great care must be taken, of course, in this process, so as not to injure the dielectric by excessive heat.

Behind each clamp a brass or copper gland should be fitted to the armouring and bonded to a proper earth bolt on the switchgear, or in the case of a joint box the copper should be connected from gland to gland with a Tee socket between and fixed to a proper earth stud on the box. The sectional area of this bonding cable should be 50% of that of the live current carrying conductor. Some are of the opinion that an armoured cable fixed by the standard cone clamp does not require extra bonding, but the author contends that it is not sufficient and that the extra bonding should always be fitted. Various opinions are expressed with regard to whether or not earth connections should have sweated sockets: where possible they should be sweated, although the Ellison Clamp Washer method of fixing connections has many merits as an alternative.

Earthing of Lighting Systems.

At most of the large works according to the reports, 75% of electric shock accidents come from lighting apparatus. Lighting everywhere seems to be often very carelessly installed. The cable and tubing, etc., in many cases have not been fixed by sufficient saddles to ensure mechanical strength. Bends and couplings are often not so tight as might be, and lock-nuts are very seldom fitted on running screws, leaving bad earth connections in the tubing. At distribution boards very few people bond the pipes together, connecting a wire from these to the earth screw on the box, and from here to a gland on the incoming feeder. It is often said that bonding pipes to a distribution box is superfluous. Large type fittings suspended from hooks on roofs with open V.I.R. cables running into them are often left unearthed; which is dangerous, especially when over concrete floors.

Regularly one comes across small drilling machines and electric grinders taken from ordinary pendant holders with no earth connection whatsoever, the users being unaware of their imminent danger should a fault occur.

On open wiring systems a cast ironclad distribution box is often used with no earth wire connected to it. Another very dangerous practice is to connect an ordinary lampholder on a length of flex and use it for a portable light. How can these dangerous practices be stopped? Earthing on lighting systems does not seem to count, excepting to the very few who realise the need.

With regard to the armoured cable lighting systems, the cable should be bonded at the distribution boards as already mentioned for tubing, and every fitting should be bonded over.

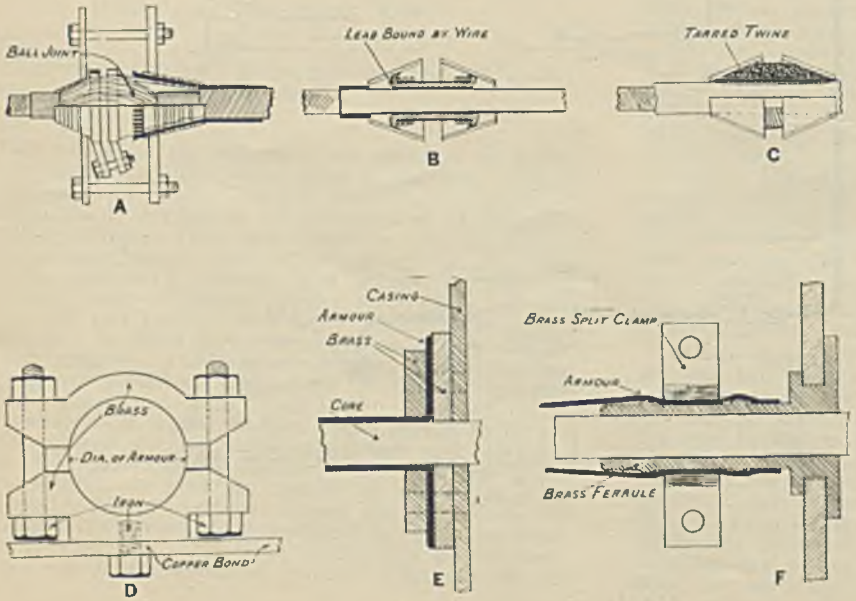

Fig. 2.

In the lead covered cable system bonding at the distribution boards should always be done. There are many designs of joint boxes in this system, but no matter what type or design, great care should be taken with the bonding of the cables in these boxes.

All lighting circuits should have a form of leakage detection. In a large factory the author at one time suggested to the chief engineer to have a set of earth detector lamps fitted on his lighting system, and after they were installed it took him a week to clear his faults, leakages which he did not realise were on his system.

Importance of Earthing.

The electrician should have a systematic routine of testing and logging his earth system. The main earthplates should be tested once every month, which would give twelve entries in the log: Table I. With regard to main cable testing, the shaft cables and dooks, etc., should also be tested systematically and logged at every test. The bond testing instrument could be used on cables where the current could not be switched off. It is not suggested to take logs of every little branch feeder, but a book could be kept showing the date when small feeders, etc., were last tested, for the sake of routine. The common experience of over-logging is that there are times when logs cannot be kept up to date and so they get dispensed with altogether. It is better to log only what is necessary and keep these up-to-date.

With regard to the importance of earthing, the earth system of an electrical installation should be treated with the same care as the "live" system. Reliance upon the "earth" system just as much as the "live" system concerns the safety of life.

Earth Plates.

The provision of a good connection to mass of earth is of special importance in colliery installations, having regard to the necessity of avoiding danger of shock. If a single earthplate having 1 ohm. resistance be used, should this be called upon to carry momentarily a current of 500 amperes such as may be necessary for a circuit breaker to operate, the earthplate would be raised to a voltage of 500 volts above earth, which would be dangerous. The first Memorandum on the Electricity Regulations (Coal Mines Act, 1911) General Regulations, July 10th, 1913, issued by the Home Office in 1914, makes the following suggestions regarding earthplates.

"Earthplates may be of copper, cast iron, or galvanised iron. A cast iron plate with projecting forks to give a large contact surface forms a good earth connection. Earthplates should be no less than four feet square, preferably in an upright position in the ground packed hard on each side with about 12in. of broken coke free from sulphur. The depth at which they are buried must depend upon the condition of the ground in regard to moisture. The place selected should be permanently wet, or at least damp."

A good type of earthplate is shown in Fig. 3. It is of ribbed cast iron ¾in. thick, 6ft. long by 2ft. broad with 14 ribs. A copper bar 2½in. × ¼in. is bolted along the top on which the main connections are fixed. The author should mention here that he does not like brass bolts as a means of fixing earth sockets or glands, especially in an atmosphere where there is a continual change of temperature. He well remembers an instance at an ore mine in the South of Scotland where he installed two new ribbed cast-iron earthplates, which had the main earth cables fixed by ¾in. brass bolts. His last duty before returning to Glasgow was to inspect the earthplates to see that everything was O.K.; to his great surprise he found one of them disconnected. The earth cable on one of the plates was 2in. clear, and the brass bolt was lying on the coke broken in two. The only explanation seemed to be that, desiring to have a safe connection, the bolt had been forced up very tightly, and with the continued expansion and contraction of the brass and copper metals and exposure to frost, the bolt had snapped. The suggestion is that either galvanised or sherardised bolts should be used. The surface contact of all sockets or contacts should always be of sufficient area to make an efficient connection without using the bolt as part of the conductor.

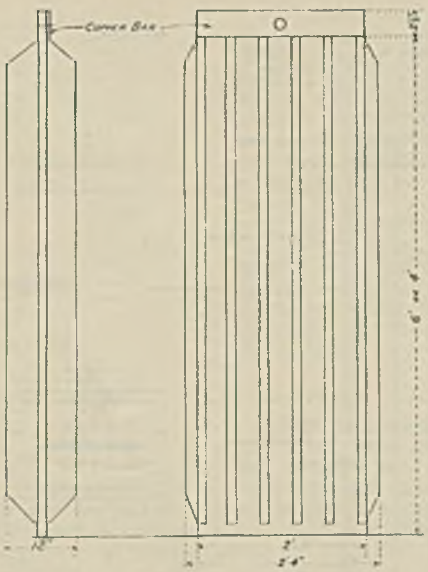

Fig. 3.

Fig. 4.

Another type of earthplate is shown in Fig. 4, made from a cast iron pipe 8ins. diameter and approximately 6ft. long, with a flange on one end. A 2in. by ¼in. copper bar is bolted approximately every 9ins. up the side of the pipe then along the top of the flange, with a sufficient length of copper left with which to fix the main connections.

Installing or Sinking of Earthplates.

First of all suitable sites have to be selected in good moist soil, free from slate, rubble, or ashes. To instal one of the cast iron ribbed plates or pipes already mentioned, a trench should be dug 7ft. deep and 2ft. 6ins. broad, stepped down as shown in Fig. 5. At the deep end the plate or pipe would be inserted resting on a wrought iron plate, to prevent sinking, with the top 12ins. below the surface ground level. The stepped part of the hole would be filled in, a board being placed 1ft. 3ins. from the centre of the plate to prevent the earth from filling in the hole. Around the plate bags of good quality coke free from sulphur would be packed. The board would then be withdrawn.

The remaining 12ins., above the top of the plate, would have a 9ins. course of brickwork built around it 2ft. 6in. square to a height of a little above the ground level. An iron cover plate would lie flat over the top of the brick chamber, and could be lifted easily when it was necessary to examine the earthplate. On lifting the cover, the copper connections to the plate could be seen at a glance: it is also an easy matter to moisten the plate and coke with water if necessary. The author has sunk a number of earthplates in this manner and they have proved a great success.

TABLE I.—EARTH LOG SHEET.

No. 1 Colliery. *Battery = 4 volts.*

DATE.	A to B +	A to B —	REMARKS.	A + BAR & B	A — BAR & B	B + BAR & A	B — BAR & A	INSULA. OF BAR A	INSULA. OF BAR B	REMARKS.	SIGN.
Jan. 16, 1929	*No test taken*	*No test taken*	*Unable to get plant shut down*	1.8 *amps.*	1.8 *amps.*	1.6 *amps.*	1.6 *amps.*	20 *megs*	30 *megs*	*Test taken on dry day. Tests low, otherwise O.K.*	*J.W.*

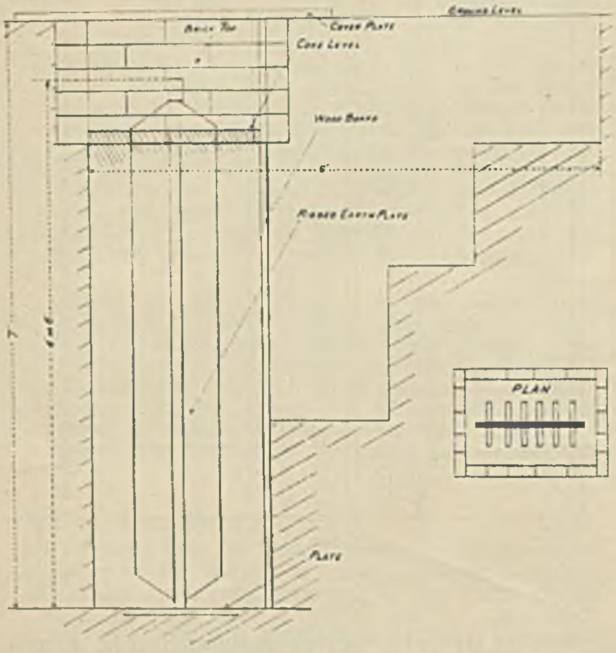

Fig. 5.

Design of Earth Bar.

As shown in Fig. 6, three copper bars are fitted side by side on insulators and bonded by two copper links. From the centre of each outer bar provision is made to connect a cable to the respective earthplates: the left outer bar to plate A and the right outer bar to plate B. A series of holes should be bored in the centre bar to take the earth connections for the system. This bar should be of substantial design and in an insulated state should give at least 10 megohms. By disconnecting both links at a period when the power is shut down the earthplates can be tested apart from the feeder system. Should it not be possible to shut down only one link can be opened. A counter check can be made by replacing this link and opening the other, although the most efficient test is with both links open.

Cables between Earthplates and Earth Bar.

The two cables or copper strips running between the outer links of the earth bar and the earthplates should be run on cleats or insulators, and in an insulated state should give at least two megohms. The reason for insulating these cables or copper strips is that, should there be a fairly long distance between the plates and links, the conductors being insulated will not upset the test readings. If the conductors are of stranded copper wire they should be fitted with sweated cast brass sockets.

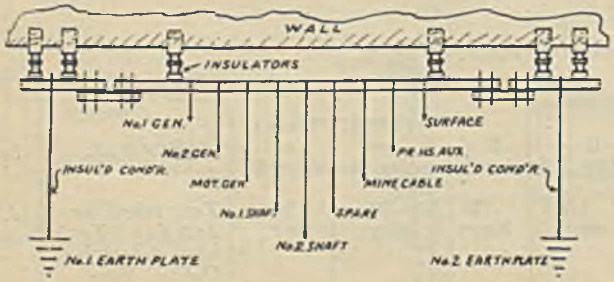

Fig. 6.

Method of Testing Earthplates.

In Fig. 7 is shown a small testing set which is easily made up. The double-throw switch is to enable current to be passed between the plates in both directions so as to counteract polarisation of the earthplates. The test readings should be two amperes at four volts.

(Here were exhibited a series of fifteen lantern slides showing testing instruments and methods of testing by Messrs. Evershed & Vignoles, Ltd.).

The following records refer to a test of an earth bar which was connected to two earth plates. Bar A was earthed to a large main water pipe, and Bar B to a copper plate sunk in the ground below the power station floor. Not being entirely satisfied with the tests taken, another test was made with a supplementary earth plate near by.

X = Supplementary earthplate.
A = No. 1 plate to main water pipe.
Bar = Earth feeders throughout system.
B = No. 2 plate sunk under power house.

Tests between

A+	and	B	=	.5	amp.	showing	low reading	at 2 v.
A—	„	B	=	.5	„	„	„	„
A+	„	Bar	=	2.5	„	„	good reading	„
A—	„	Bar	=	2.5	„	„	„	„
B+	„	Bar	=	.5	„	„	low reading	„
B—	„	Bar	=	.5	„	„	„	„
X+	„	B	=	.5	„	„	„	„
X—	„	B	=	.5	„	„	„	„
X+	„	A	=	2.0	„	„	good reading	„
X—	„	A	=	2.0	„	„	„	„

From the above results it will be seen that the reversed polarity readings are the same, and that plate B was very low at .5 amp. in each test. This was found to be due to the plate being under the concrete floor and in a very dry condition. Holes had to be drilled in the floor and the plate watered at intervals to bring it up to the standard reading. Periodical tests are always taken now and are very necessary owing to the continual drying of the ground.

Fig. 8 shows methods of testing cables and joint boxes.

Earth Leakage Indicators.

Roughly speaking there are two types of earth indicators:

(1) Those used for systems which are entirely insulated from earth.

(2) Those used for systems which are earthed at a point generally the neutral.

Dealing with the first section, these can be subdivided into two: (a) Indicators used on high tension circuits; (b) Indicators used on low tension circuits.

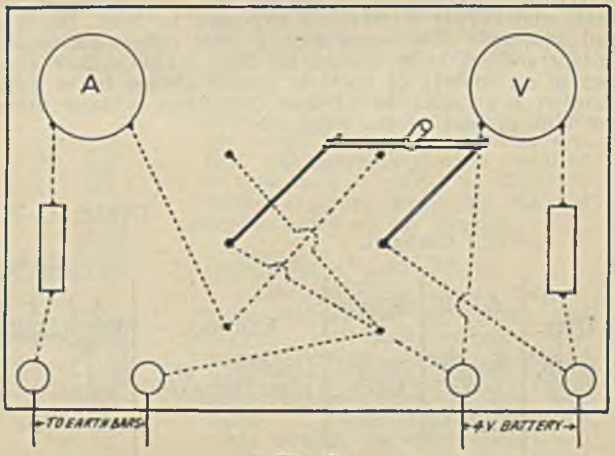

Fig. 7.

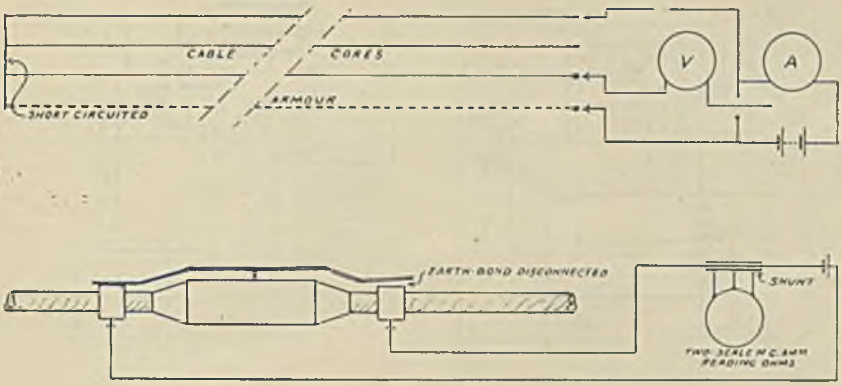

Fig. 8.

For extra high tension Neon lamp indicators are now largely used in the United States, and are also known in some cases in this country.

This Neon lamp indicator simply consists of a well insulated base upon which are mounted three Neon tubes, the whole being caged in an earthed metal case. One side of each Neon tube is connected to the high tension bushing of each phase, and the other side of each Neon tube is earthed. No current will flow until an earth fault occurs on the line, whereupon the lamp connected to the faulty phase will glow brightly:- see Fig. 9.

High Tension Indicators.

For high tension indicators the author prefers the static ground detectors, A.C., for unearthed systems. There are two types made by Metropolitan-Vickers Electrical Co., Ltd., each of which the author has installed and they have proved very successful.

Type 1.—Round, for use on 1, 2 or 3-phase circuits.

Type 2.—Bulls-eye, for use on 3-phase circuits only.

The instruments indicate when faults occur on the mains of an alternating electrical system, and so permit prompt action to be taken to isolate the faulty feeder. The principle is that of a differential electrostatic voltmeter. In the single phase instrument two fixed vanes are connected through condensers to the mains, and an earthed movable vane is placed to take up any position between them. When the potentials between the mains and earth are equal the movable vane takes up a mid-position, and the pointer attached thereto indicates zero. Should the potentials for any reason become unequal, the movable vanes move to the right or left, the pointer indicating accordingly. For two-phase and three-phase systems two single phase instruments are used, with a combination of condensers: Fig. 10.

The bulls-eye type for three-phase circuits has three fixed vanes, one for each phase, and an earthed movable vane which takes up a position according to the balance of the potential between the three mains and earth.

The condensers for these instruments can be slipped over the cables if the cable does not exceed $\frac{7}{8}$in. diameter, and the voltage is not over 13,500 volts. It should be noted that there is no direct connection between these instruments and the line, and the terminals of the instruments do not occasion any danger: Fig. 11.

Low Tension Indicators.

Metropolitan-Vickers Electrical Co., Ltd., also make a very neat and reliable A.C. and D.C. leakage indicator. The moving coil indicator is only suitable for use on two-wire D.C. insulated systems; the moving iron indicator may be employed for either D.C. or A.C. single or polyphase systems: Fig. 12.

Indicators for Earthed Systems.

Dealing now with indicators for earthed systems, this section can be again sub-divided into two further sections: (c) Those systems in which the earth lead is accessible; (d) Those systems in which the earth lead is not accessible.

Dealing with section (c) it is the general practice to insert a bushing type transformer over the earth lead. The capacity of the transformer would be determined by the size of the plant. In the secondary of this transformer an ordinary ammeter is placed, and in some cases, a relay, the ammeter reading the earth current.

In the case of section (d) it is usual to adopt the double star connection, the ammeter being connected in this case to the three secondaries: Figs. 13 and 14.

Evershed's D.C. leakage instruments are especially good, as they provide:

(1) A continuous indication or record of any inequality in the insulation of the mine.

(2) Means of determining in an instant the absolute value of the insulation resistance of each main.

(3) Means of obtaining the value of the leakage current by a simple calculation.

Evershed and Vignoles, Ltd., also make a "Megger" earth tester for testing the resistance of the earthing connections made to metal structures, such as transmission poles, tanks, bridges, etc. It has an ingenious device to provide A.C. current for the section of the testing circuit which passes through the soil, and direct current for the measuring instrument. The use of

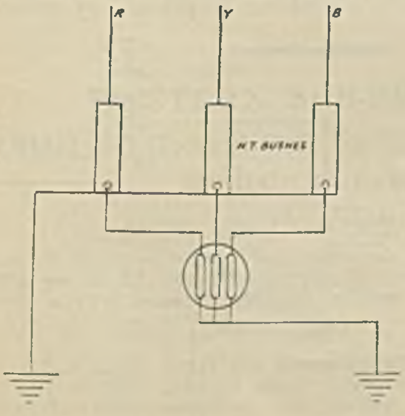

Fig. 9.

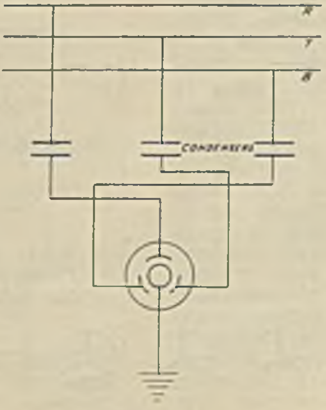

Fig. 10.

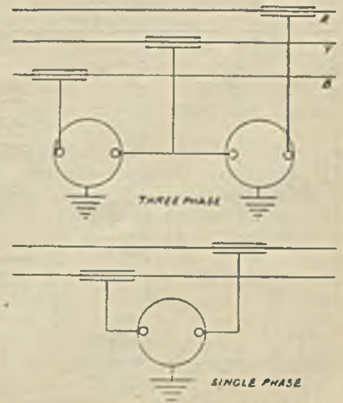

Fig. 11.

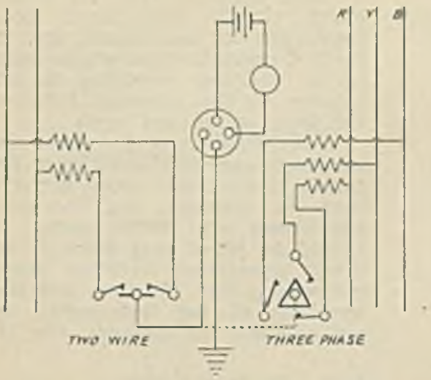

Fig. 12.

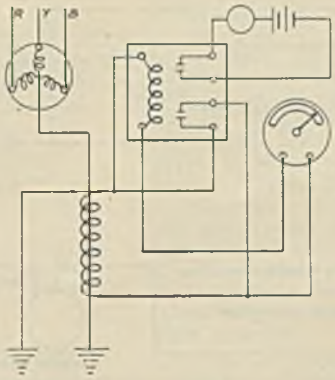

Fig. 13.

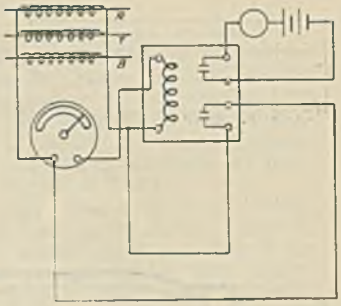

Fig. 14.

an A.C. in the soil prevents external sources of error due to such as vagabond soil currents and back electromotive forces, from affecting the accuracy of the tests; while the direct current in the instrument section of the testing circuit permits a moving-coil instrument to be used, having powerful working forces and a uniformly divided scale.

Earthing the Neutral Point.

Some few years ago there were serious differences of opinion among electrical engineers as to the advantage of earthing the neutral point of a three-phase system, and the question of "To earth or not to earth" provoked some interesting arguments. The main advantage claimed for an insulated system was the possibility of running a system temporarily with one phase earthed through a fault, but it is usually found that under this condition other faults almost immediately appear on the unearthed phases as they are at the full system voltage above earth, and weak points in the insulation of cables or machines break down.

A connection between the neutral point and earth forms the best possible discharge path for over-potentials due to electrostatic charges and other causes, and this fact alone is sufficient to justify neutral point earthing on large systems.

Every form of sensitive protective device is designed to disconnect a fault in the early stages when it is an earth fault only and before it develops into a fault between phases. Since we see that it is advantageous to earth the neutral point, what is the best system to consider? If the neutral point is earthed direct an earth fault on one phase is equivalent to a short circuit, the resultant surge of which may be serious to the system. It is the standard practice to insert a resistance between the neutral and earth, and in doing so great care must be taken to see that the value of the resistance is such that it will pass enough current to operate the least sensitive relay on the largest feeder.

It is not possible to ensure that the whole of a generator is protected as, however low the resistance may be, a certain definite voltage is required to pass sufficient current through the resistance to operate the generator relay; and if a fault occurs near the neutral point the voltage available may be insufficient to pass the necessary current through the resistance.

On a generating system the correct place to make the earth is at the star points of the machine, but if the star points are connected solidly to a common earth bar there may be a circulation of third harmonic currents between the machines, and although the value of the currents may not cause much heating in the windings the accuracy of the instruments may be affected.

It is necessary to earth the neutral point of one machine only, but a common resistance and selective switches must be fitted so that any one machine may be earthed.

The arrangement commonly used for earthing the neutral point of a H.T. system is shown in Figs. 15 and 16. The ammeter is operated from a current transformer of special design, the magnetic circuit becoming saturated when the primary is carrying a heavy current, so that the scale is very open at low readings but gives an indication of a fault. If a low reading recording ammeter is used, an automatic switch should be provided to short circuit the ammeter when a fault occurs. The switch may have extra contacts to close a warning bell. Fig. 15 shows an alternative arrangement of selector switches so arranged to earth only one machine at a time.

Earthing resistances may be made of metal grids or carbon powder. Carbon has a negative temperature coefficient, thus allowing the earth current to increase in value generally and reducing the shock to the system. Metal grids act in the opposite manner and it is not often certain that an increasing current will operate protective relays if they should have failed to operate with the initial rush of current.

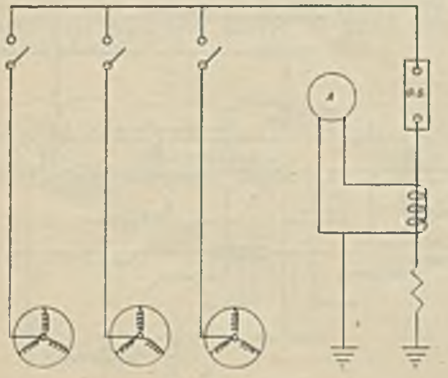

Fig. 15.

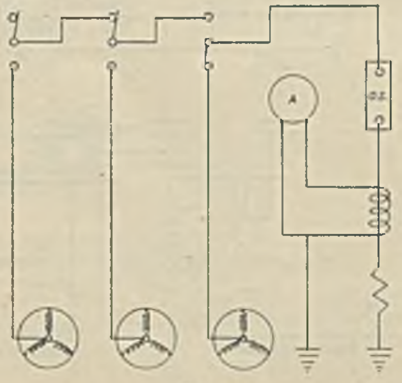

Fig. 16.

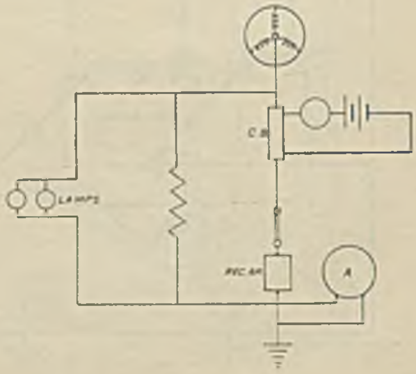

Fig. 17.

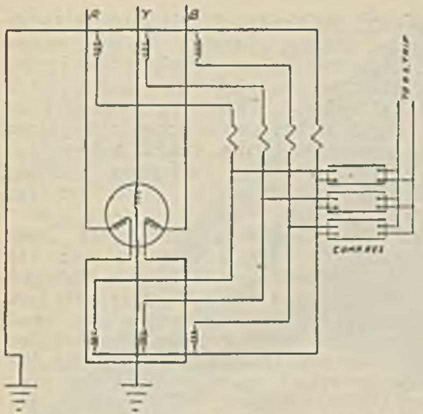

Fig. 18.

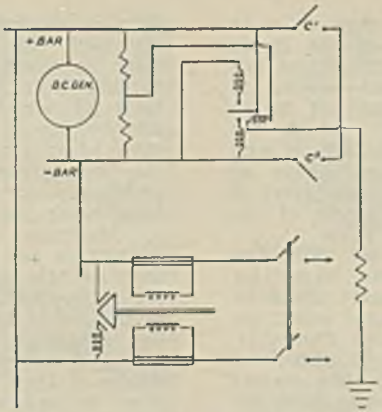

Fig. 19.

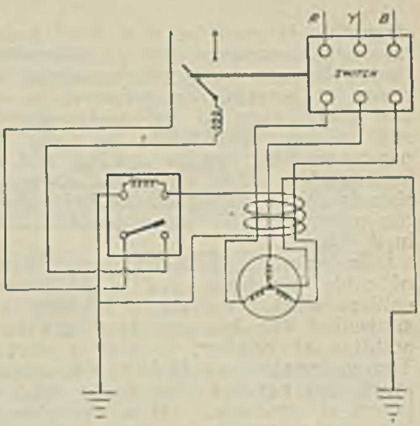

Fig. 20.

The neutral point on medium-pressure systems is usually earthed direct through a circuit breaker which opens and puts a resistance into circuit when a fault occurs: Fig. 17.

Protective Gear for A.C. Systems.

There are quite a number of A.C. protective systems to choose from, including Merz Price (Fig. 18), Merz Beard, Merz Hunter, the Williams Rowley device, the Bowden Thomson system, the McColls biassed system of protection and many others. For D.C. there is the Couse-Rosebourn method: Fig. 19.

The Ferranti-Field system of core balance earth leakage is a simple protection for operation on earth faults: Fig. 20. The three ends of the machine windings are taken through one current transformer, and the neutral is also taken through before being earthed, in order that fault current flowing in any phase due to an external fault will be counter-balanced by the return current flowing in the neutral point earth connection. Under healthy conditions the vector sum of the currents in the three phases is zero, and no current is induced in the secondary, but an earth fault upsets the balance and a secondary current proportional to the fault current is induced. As already stated this system only operates on earth faults and not on faults between phases.

It is not intended to go into the above methods of protection as many papers have already been written on this subject, but it is important to note that on insulated neutral systems many fatal and non-fatal accidents would have occurred and which would have been averted if a protective device had been installed.

The author concludes with the feeling that he could have written much more on this subject: he trusts, however, that sufficient has been said to prove the necessity of adequate earthing and periodical testing as a sure means of increasing the factor of safety and minimising the number of accidents.

WESTERN SUB-BRANCH.

Cables and Control Gear for Use Underground.

GORDON RUTTER.

(*Paper read 12th January,* 1929).

It is proposed in this paper to deal with a few of the points of general interest in connection with cable and control gear suitable for mining work underground.

CABLES.

For many years the improvements made in the electrical supply industry have been materially controlled by the cable position, and to-day electrical progress, whether on telephone or power side, is to a remarkable extent in the hands of the cable maker. On the power side the cry is for higher and higher voltages to cut down transmission costs, and here the cable makers practically control the position and, fortunately for the electrical industry, they maintain the high prestige for which British made cables are so justly famous.

In dealing with cables suitable for use underground, the following classes are available for choice: (1) Paper Lead; (2) Paper Bitumen; (3) Vulcanised Solid Bitumen; and, for some classes of work, Rubber Insulated cables are used.

In the installation of paper lead cables perhaps the greatest draw-back to an efficient job has been the difficulty of making a really good joint. The jointing of paper lead cables in the fiery mine was, until recently, a very difficult proposition, since it was practically impossible to make a good joint without the use of a blow lamp or fire for bonding the lead.

The paper of paper cables is hygroscopic and loses its insulating properties rapidly on exposure to moisture; this is a very serious draw-back in mining work since moisture is the greatest enemy to be fought in the majority of mines, and it is obvious that the least crack in the lead would admit moisture and yards of cable might be ruined before the fault would be noticed.

The phenomenon of the cracking of lead cable has received little attention until recently. Cracks have generally been found to have commenced on the inside of the sheath and were usually free from corrosion. The lead in the region of the crack was not distorted and definite evidence was obtained that, where the sheathing failed, the cable was in a state of vibration. Alternating stress tests on lead and its alloys have shown that lead has a very low fatigue limit, and fractures obtained in pure lead test pieces have been found to be similar in all respects to those found in cable sheathing that has failed. The ultimate conclusion arrived at by the research workers was that the cracking is, more often than not, a fatigue type of failure.

The lead covered paper cable may be ideal in a situation where once fixed it remains permanently, such as a shaft cable, but it is not to be recommended in places where it may have to be moved, say, for timbering or other repairs.

The paper used for this class of cable is specially selected for its electrical and mechanical properties. It must have sufficient tensile strength combined with a certain amount of stretch to enable it to withstand the forces to which it is subjected during the lapping process and during the bending of the finished cable. Obviously it must be free from chemicals left over from the paper-making process, not only in order that its ageing properties may be good, but also to ensure no possibility of action with the copper conductor.

The requirements of a good paper impregnating compound are, first and foremost, that it must have a high specific dielectric resistance and a high breakdown strength. It must be of a good greasy nature so as to lubricate the paper and promote sliding of the layers during bending of the cable, whilst having sufficient viscosity at working temperatures to prevent flowing to the lower parts of the cable, and it must not be so stiff at low temperature to cause trouble due to the paper cracking during coiling and uncoiling. A well impregnated cable on being opened up will have an abundance of compound between the different layers of the paper and the paper itself will have plenty of life in it.

In reference to vulcanised bitumen cable, this class of cable has been, and is, in considerable favour for colliery work. Vulcanised bitumen is brought about by subjecting the bitumen to a heating process after the addition of sulphur, to give it strength and durability. The material is applied to the conductor by extrusion, taped and braided, and finally lapped with one or two layers of armouring. It is advisable to ensure solid filling of the strands to prevent ingress of moisture from the ends.

The popularity of this class of cable, in the opinion of the author, was due to the fact that it was not so heavy as the paper lead and more easily jointed. The ease of jointing, therefore, did away with the need of employing an expert jointer, for whom there would be hardly sufficient work in one colliery.

For years some collieries have used nothing else but vulcanised bitumen cables, but now in these days of high voltages, and because the current density of paper covered cables is higher than that of solid bitumen, the paper bitumen sheathed cable is being installed on a large scale. This class of cable seems to suit the colliery engineer's purpose, and with a reasonable amount of care during installation can be depended upon to last for many years.

The treatment of trailing cables provides ample material for a paper of its own and it is not proposed to attempt to go into any detail here. The history of trailing cables for colliery practice goes back to the time when two vulcanised single-conductor cables tied together at intervals of a foot with tarred string were in use. The next step was to enclose the cables in hose pipe, an arrangement which proved to be very unwieldy; this led on to rawhide leather braided cable, ordinary leather, vulcanised rubber whip cord sheathed, and finally to the cab-tyre sheathed.

The troubles that arose in the earlier types were due chiefly to the fact that the cable was not sufficiently flexible in either its conductor or protection; but as soon as the manufacturers realised this, steady progress was made in the right direction until we have to-day a cable practically reaching perfection for safety, reliability and durability.

The present day trailer is composed of four or five cores of flexible copper conductors well insulated from one another; the cable is cab-tyre sheathed and in some cables the conductors are enclosed in a sheath of braided copper wires. When such a cable is used in conjunction with specially designed switchgear complete protection is afforded to any machinery under control.

Many collieries still favour the use of direct current and where the length of transmission is short, D.C. seems to have nearly everything in its favour. In the case of D.C., either single or multicore cables may be installed since, as its name implies, the current is continuous and the lines of force that surround the conductor are more or less in a static state. When, however, A.C. is used, only the multicore cable has to be dealt with. If single core cables were adopted, each line would act as a transformer with the armouring acting as a secondary; to avoid getting these induced currents it is necessary to enclose all the conductors forming the same circuit under the one metal sheath.

In highly insulated lines, transmitting current at voltages over medium pressure, static charges have to be dealt with. At the moment of switching off a current, the electro magnetic lines collapse on the conductor that gave rise to them, setting up an electro motive force in that line, tending to send a current in the opposite direction. The switch having been isolated, there is no path for the discharge of this current, with the result that the line remains charged. It was customary to discharge the line before working on it by flashing over the conductor to earth by means of a piece of well-insulated cable. This was a dangerous practice, for in the event of the cable being alive from some other source, disastrous results would follow.

The present arrangements of adapting existing switchgear for automatic discharge to earth are far from being satisfactory.

Multicore cables, like everything else, have their advantages and disadvantages. The advantages are: (1) there is only one cable to handle; (2) having installed the cable, it is not necessary to bond it every 100 feet as demanded by the rules for single cored cables; and this advantage does not end here, because there is the avoidance of all the time and trouble of inspecting the clamps if they are to be relied upon to fulfil the purpose for which they were intended. The case is reversed, however, if the cable is of such a diameter that it can only be sent down in short lengths and may not be flexible enough to go around corners with a sufficiently easy bend.

The intake main roads and airways should be used whenever possible for main feeders, as these roads generally have sound roofs and sides and are fairly free from falls. Thus the cables may be fixed in a permanent manner either by cleats or suspenders. In workings where there is liability of damage from roof falls, the cables should be suspended in such a way that the suspension thongs will readily break away.

When installing cable the loaded drums, if possible, should be taken forward into the workings and then rolled back, paying the cable off as they travel along. It is highly undesirable to mount the drum and pull the cable off, as it involves the risk of damaging the cable. The laying of cable in-bye is really a very important part of a successful installation, and much more care should be given to this part of the work than it generally receives. The number of men allocated to this part of the work is very often so limited, that horses and even mechanical power have to be used to get the cable into position. Given sufficient time and men, cable laying underground need not be the bogey it appears to be, and the cable can be hung in position in exactly the same condition as it left the drum.

The effect of mine water depends, obviously, on the composition of the water, but in most cases damage is greatly accelerated when the galvanised coating of the wire has been rubbed through. A very efficient protection for exposed armouring in wet places is to tape the cable with strips of brattice cloth and then treat it with a good coat of hot bitumen or tar.

Whenever possible a dry spot should be chosen for the joints. Jointing underground to-day does not present any special difficulties. Practically all joints are mechanical and if the proper connectors are used, together with ordinary care, a really efficient joint can be made.

The joint box for underground use has practically reached perfection for simplicity, compactness and mechanical strength; but most colliery electricians would like to see a box made of metal other than cast iron; if not the whole box, at least the glands for the armouring should be of another metal, for anyone who has installed a number of boxes knows how easily it is to crack the gland by just giving that little extra turn to the nut.

An entirely novel method of plumbing and jointing lead sheathed cables has been introduced by the "automatic plumber," which employs electrical methods and so facilitates its use in fiery mines. It consists of a series of copper dies which are themselves heated by detachable electrically heated elements designed to raise the dies to a predetermined temperature. These dies have a taper bore and are used in conjunction with lead alloy cones supplied by the makers, which are lined with an alloy having a higher tensile strength and lower melting point than lead. If the temperature of the dies is limited the lead sheath and insulation of the cable are immune from damage, but the alloy lining

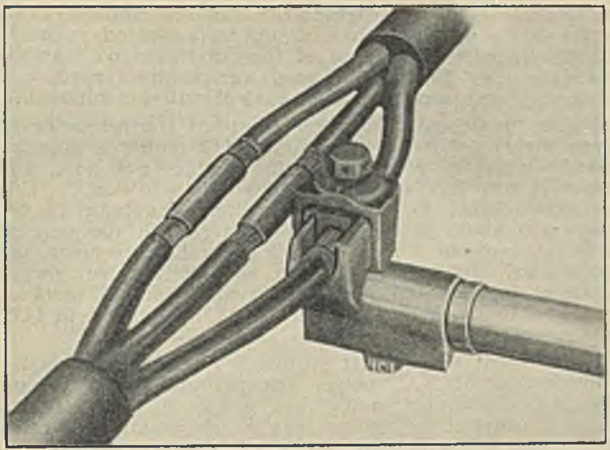

Fig. 1.—"The Automatic Plumber."

of the fixing cone becomes molten. The use of special flux and compression of the lead alloy cone by means of the taper die ensures a perfect union with the lead sheath of the cable, so that the joint will withstand 250lbs. hydraulic pressure. The maximum current required is 45 amps. at 12 to 14 volts. With A.C. supply a one K.W. transformer will meet all requirements. (See Figures Nos. 1 and 2).

To obtain the most economical section of a feeder the Kelvin Law is used. This is: "The most economical size of a cable is that in which the annual cost of wasted energy is equal to the sum of the annual interest, depreciation and repairs on that part of the capital cost which increases with the size of the conductor."

The trouble in applying this law is that the yearly I^2R losses which depend upon the square of the current and the time it is flowing are difficult to arrive at. This can be done by drawing up an approximate daily load curve and working out the average value of I^2. (See Figures Nos. 3 and 4).

This theoretical section cannot always be adopted in practice because the current density may be so high as to raise the temperature above the safe limit, or the pressure drop may be greater than can be conveniently dealt with. Each case must therefore be ultimately worked out on its own merits.

SWITCHGEAR.

Although mining accidents are due directly to the use of electricity have been of rare occurrence, the miner is justified in his demand that all electrical gear for installation underground shall be designed and constructed far more carefully, and with a much higher degree of safety, than that for use on the surface. The mining apparatus must be so constructed that the attendant, however ignorant he may be, cannot be exposed to any danger from contact with live parts. It must be suitable for operation in damp and dusty localities without deterioration and must be protected against dripping or splashing water.

In order, therefore, to utilise fully the advantages of electrical power, it is essential that mining electrical control apparatus should comply with, and possess to the highest degree, the following conditions: (1) Safety; (2) Reliability and Flexibility; (3) Economy in floor space and head room; (4) Accessibility for inspection and cleaning.

These conditions led up to the development of control gear of the ironclad type and of the oil-immersed unit type.

The switchgear can be divided into two main types, (1) Air-break; (2) Oil-break.

For use underground, both types must be iron-clad, flame-proof, and be covered with the certificate of the University of Sheffield special mining testing department.

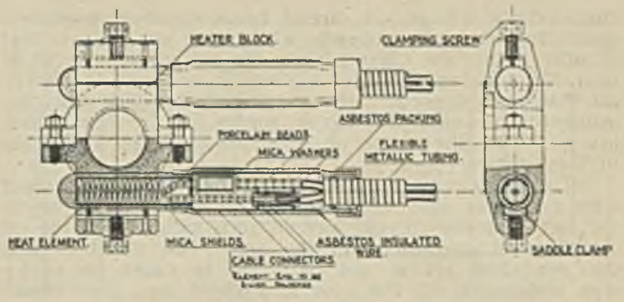

Fig. 2.—"The Automatic Plumber."

Air-break switchgear is to-day confined chiefly to lighting, and in some cases to gate-end switches for coal-cutter installations.

For use in fiery mines all containing cases should be provided with broad machined flanges so that any products of combustion are cooled to a safe temperature before passing into the outer atmosphere; and all glands, cable boxes, etc., shall be absolutely gas and watertight where connected to the castings. If, for any reasons, the flanges are turned inwards instead of outwards, they must be provided with bottomed holes.

In the design of air-break switchgear there should be ample clearances and long and rapid breaks. More attention should be paid to the actual working mechanism of the switch. How often do we see massive cast iron cases enclosing the most flimsy of mechanism, where material has been cut down to a minimum and this again operated by a heavy cast iron handle, with the result that if the least thing goes wrong inside, with the large amount of leverage available the whole switch may be rendered useless in one operation!

During recent years large strides have been made in the lighting of underground main roadway and partings. This class of work stresses very forcibly the advantages to be gained by installing unit type switchgear where, in the event of new branch circuits being required, the unit can be easily and safely added to.

Air-break switchgear for coal-cutter work holds an advantage over the oil circuit breaker in the fact that it is not bound to be fixed perfectly upright and can be more easily transported over rough ground. It is generally of very heavy design due to the liberal use of materials and which allows it to be hauled along without risk of injury to its parts.

The oil circuit breaker has during recent years been rapidly developed for mining service, where compact, totally enclosed, dust-proof and drip-proof switchgear is required. In its earliest forms it was little more than an ordinary switch immersed in oil, but the subject of the control of electricity has developed to such an enormous extent that, as a result, the oil circuit breaker being one of the fundamental units, has also been in a corresponding state of development.

Oil switches are almost invariably used on alternating current systems owing to the fact that the main

Fig. 3.—Kelvin Rule.

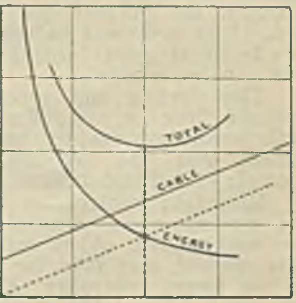

Fig. 4.—Kelvin Rule modified for Insulated Cables.

characteristic of an oil circuit breaker, upon which its successful operation depends when used on A.C., is that of interrupting the current when the current wave is at, or near, its zero value. The oil switch prevents the heavy arc that would occur with an air-break switch and consequently prevents the heavy surges in the line which are so often the cause of breakdown of the insulation of the systems.

The oil circuit breaker cannot be said to have met with the same amount of success in D.C. work, due to the fact that the current has no zero value when the oil can flow in and interrupt the arc. The result is that the persistent arc is not only apt to cause an explosion under the oil, but also in a short time decomposes the oil and makes it unfit for further use.

Various methods have been advanced to limit the amount of arc energy. The simplest construction of current carrying and arcing contacts includes one or, at the most, two breaks, spring loading for increasing the natural acceleration due to gravity, and a large volume of oil. This construction has been applied to reduce the arc energy to an economic minimum.

Some advance in regard to current breaking capacity has been made in recent years, and to-day it is the controlling factor in the design of oil circuit breakers. The B.E.S.A. definition of breaking capacity of an oil immersed circuit breaker is: "The maximum K.V.A. which the circuit breaker will break under prescribed conditions, at stated intervals, a specified number of times." The value of the maximum K.V.A. is the product of the rated voltage and the actual current at the time of separation of the contacts. It is evident, therefore, that the condition which determines the design and rating of a breaker should naturally be the worst that it may be called upon to withstand. This means that it must be capable of withstanding the maximum K.V.A. likely to exist at the instant of a short circuit.

In the general design of the breaker, the two principal considerations would be: (1) Clearances; (2) Strength.

The clearances between the live parts and earth and between the live parts of opposite polarity must be ample, keeping in mind the worst conditions that can occur. The oil tank should be of sufficient thickness to withstand any internal explosions due to the formation of combustible gases from the oil. It should be lined with some suitable insulating material which generally takes the form of three or five-ply wood, fitted so that an oil space is interposed between it and the tank.

Multi-tank breakers are seldom used below ground unless a breaker is required for controlling the main feeder at the pit bottom, and then only for circuits of the order of not less than 150,000 K.V.A.

For underground work, there are definite advantages in using a single tank breaker, since the whole of the oil is available for cooling purposes and only one tank has to be handled for inspection. When the time for inspection is often limited, simplicity in obtaining access to the required parts may be said to be a distinct advantage.

The choice of motor control gear depends very largely upon the type of motor used and, more particularly, the purpose for which the machine is intended. It is proposed to deal very briefly with the various technical points arising out of the various methods that can be adopted.

The starting and speed control of D.C. machines presents little or no difficulty. For the uses to which D.C. motors are adapted underground we can divide the control gear into two general classes: (1) Rheostatic control; (2) Field control.

Rheostatic control, as the name implies, is simply the placing of a rheostat or resistance in series with the machine, the object being to cut down the current. This method may take the form of a wire wound starter or barrel controller coupled with a cast iron grid resistance. The latter method is used very largely in the control of haulage motors. By adjusting this resistance, any speed between crawling and full speed can be attained. There are two disadvantages to this method: (1) the rheostat carries the full armature current, so that a good deal of power is wasted in heat; (2) the speed is a function of the current as well as the resistance, so that if the load varies, the speed will also vary and accurate speed control will be impossible.

The field control method of speed control is based upon the fact that the speed of a D.C. motor is approximately inversely proportional to the flux per pole, and hence if this flux is varied the speed will vary. This is accomplished by means of a shunt regulator in the case of a shunt machine, and a diverter in the case of a series machine. This method is both convenient and economical but, obviously, it will only give speeds greater than normal. Thus a combination of methods one and two will give all that is to be desired in D.C. control gear.

In recent years great strides have been made in the introduction of A.C. power underground, and by now the A.C. induction motor has practically been placed upon a pedestal by mining men as an example of reliability coupled with a minimum of attention. Except in the case of small motors it is seldom permissible to switch on the full line pressure when the motor is at rest, not only on account of the large current that would be taken (which would be round about three to six times full load current), but also because of the need of increasing the starting torque.

A squirrel cage motor, while at rest, can be regarded as a transformer having a small air gap in the magnetic circuit and a short circuited secondary. Such a transformer would take a very high current if full voltage were applied to its primary winding, and therefore it is necessary to apply a reduced voltage until the rotor is well under way. This reduced voltage can be obtained very conveniently by the use of either a star-delta starter or an auto-transformer.

An auto-transformer starter is comprised of an auto-transformer used in conjunction with a change-over switch. The heavy current required at starting is supplied to the motor at a low pressure from the tappings of the transformer, whilst a small current at high pressure is drawn from the mains. The auto-transformer can be made much cheaper than the ordinary transformer for the same capacity and voltage ratio, since it requires less copper.

For speeds greater or less than normal it is convenient to change the number of poles. This is best explained by the formula $N = \frac{60 f}{p}$, where N = r.p.m., f = frequency of supply, and p = number of pairs of poles. The stator can be wound so that it can be connected to give two different numbers of pairs of poles. This cannot be done easily except when one number is double the other, giving a low speed of half full speed. (See Figure No. 5).

For machines requiring only a low starting torque, i.e., below 50% of full load torque, the star delta starter appears to be ideal. It may be regarded as a special case of the transformer starter, where the stator windings are used as the transformer. When starting, the three phases of the stator are joined in star, so that each phase has $\frac{1}{\sqrt{3}}$ times the line pressure applied to it. When running, the phases are joined in delta and the full line pressure is thus applied to each phase.

When starting with the phases in star, the phase current is only $\frac{1}{\sqrt{3}}$ times the phase current when the phases are joined in delta at the same voltage, consequently, since the voltage per phase is reduced to $\frac{1}{\sqrt{3}}$ the starting current is $\frac{1}{3}$ of what it would be were the motor switched in delta direct on to the line. This change-over is brought about very simply by the use of a four-pole switch.

For machines having wound rotors, the control is brought about by the insertion of resistance in the rotor circuit. The control gear may take the form of a barrel controller and resistance, similar to that used in D.C. work, or else a liquid controller may be used. The liquid controller has the advantage that the speed can be increased evenly from slow to full speed and thus all unnecessary strains on the equipment are entirely avoided. This method is by no means efficient, but where machines such as haulages are considered, ease of adjustment to suit the load calls is the first consideration. The insertion of resistance in the rotor phases not only reduces the starting current, but at the same time provides a means of increasing the starting torque. (See Figure No. 6).

About 18 years or so ago there was a great outcry by mining men for standardisation of switchgear and control gear, and to-day some firms have gone a very long way in accomplishing this. Standardisation is a great thing, providing it does not interfere with development. Such things as cable end boxes, plugs for trailing cables, etc., are typical examples for standardising.

The main point in standardisation is the saving in spares. Another channel through which standardisation could be effected would be in H.P. and speed. This could be very well carried out on three-throw face pumps. These machines could be the same H.P. and speed and have the same bed plate and outside dimensions; the result of this would be that only one spare machine would be required.

The advisability of oil immersed D.C. control gear has been discussed time and again in papers on control gear, without arriving at any definite conclusion. It is a well-known fact that the continuous arc of D.C. does carbonise oil more rapidly than an A.C. arc, so that the only way out seems the more frequent renewal of the oil. Whether this justifies oil immersed D.C. gear it is difficult to say. The heavy carbonising of the oil necessitates more frequent inspection and greater care in wiping off the carbon deposited on the mica insulated bar holding the finger contacts.

In conclusion it cannot be stressed too strongly that, for smooth working, properly organised periodic routine inspection must be established. If this is done conscientiously, together with the periodic testing of earth bonds and insulation, and records kept in such a way that they can be easily referred to, then there should be no more worry attached to mining electrical work than to any other branch of the electrical industry.

Discussion.

THE CHAIRMAN, in congratulating Mr. Rutter upon an admirable paper, said that he had covered a large amount of ground of much importance to electrical engineers. The younger members would observe from the practical parts of the paper that Mr. Rutter had obviously seized every chance in his practical experience of keeping records in such a way that he could bring them forward to help others. Two points in the paper struck him as requiring comment from the older members. One was the decided opinion expressed on the use of paper bitumen cables, and the other, the author's apparent preference for air break switches for gate ends.

Mr. YATES referred to the fact that this was a paper read by a Student Member, a paper very carefully prepared and dealing with a subject which could not fail to be of interest to all present. The author had stated that the cause of fracturing of the lead sheath on paper-lead cables was vibration, but it was quite possible, if not probable, that such fractures might arise from other causes in conjunction with vibration. He would be glad to know whether, in cases where such fractures had been observed, any difference had been noticed between the structure of the lead at the point of fracture and its structure elsewhere. He was inclined to the belief that there must be differences in the metal itself, unless these fractures occurred at points where the cable was subjected to unusual mechanical strains.

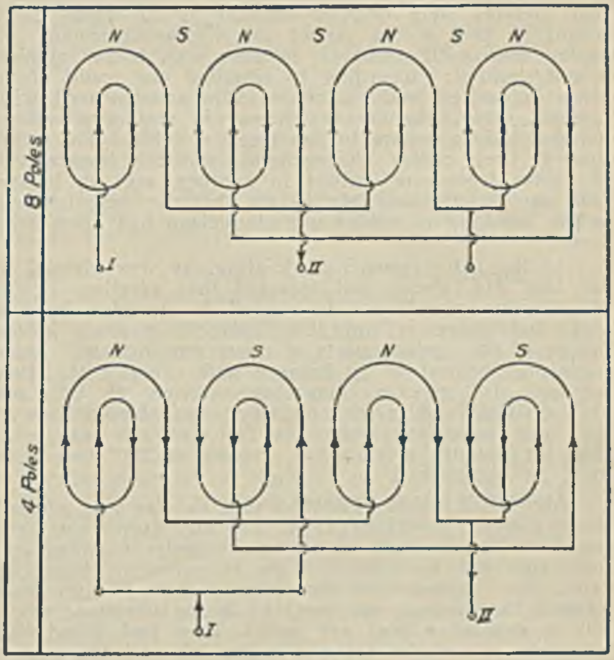

Fig. 5.

Mr. Rutter seemed to think that the use of oil-immersed circuit breakers on D.C. systems presented difficulties, and he (Mr. Yates) was inclined to agree with him. It was largely a matter of the careful selection of a suitable type. There were such circuit breakers on the market; he had used them in the collieries with which he was connected for many years and had yet to experience his first breakdown with one of them. In making a selection there were certain features which should be looked for: firstly, a high speed of break; secondly, they must have more than one break per pole; thirdly, upon rupturing the circuit the arc should be drawn downwards into the oil. If a circuit breaker embodied these features, and if it was filled with a good quality non-sludging oil, the oil-immersed circuit breaker was not only safe, but a desirable protective device for D.C. circuits. He did not approve of the use of oil-immersed drum-type controllers on D.C. systems, his experience being that they were a nuisance on A.C. work, and would constitute a positive danger on D.C. systems.

Mr. W. M. THOMAS said that in the Report of the Electrical Inspector for Mines were many references to the important points raised by Mr. Rutter. Mr. Rutter in his opening had given a very comprehensive view of cables, and he (Mr. Thomas) agreed with Mr. Isaacs

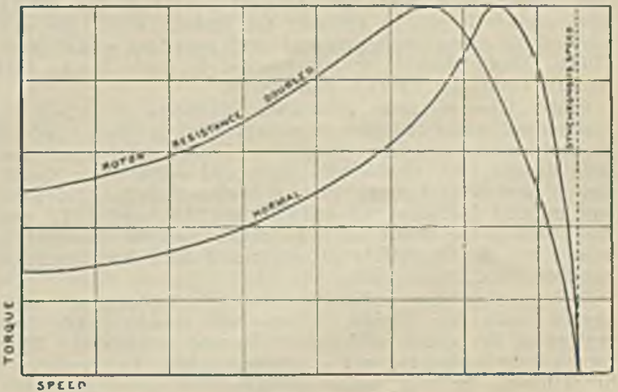

Fig. 6.

that arriving at a decided opinion as to which cable would be best was a matter for discussion among the more experienced members, because even to-day opinion is not decided; according to situation one could argue for a vulcanised solid bitumen cable as compared with a paper cable. In his experience, in certain situations he had had to resort to the bitumen cable. The question of long cables underground, and the transference of cables from one district to another, was an important one to practical electricians, because unfortunately in the handling of cables untold damage had often been done.

In the little resumé on jointing, he was pleased to see that Mr. Rutter put forward that excellent device of precision plumbing. In regard to switches, he had said that there is not that balanced accuracy in the design of the various parts of many put forward. Some parts may be out of all balance with others. Mr. Rutter had also given a comprehensive view of A.C. and D.C. control, and in his conclusion had stressed one of the most important points to the electrical man, viz., that for smooth working, a periodic routine inspection must be established.

Mr. HEZEKIAH THOMAS said he was very pleased to be present, especially as he and Mr. Rutter had been together for the last six or seven years between college and the collieries. With reference to telephone cable, Mr. Thomas said that some years ago they were advised to use twin cab tyre sheath for telephone work, but in practice it had not paid. They had found that in damp places the tin was eaten off and the copper conductors rotted, whereas bitumen cable installed 10 or 12 years ago was still going strong. He believed the twin single armoured bitumen cable still held the field for telephone work in damp collieries.

Regarding single armoured cable, he said that when converting from the old D.C. plant to the new system of A.C., they had a lot of single cables on hand, and in one particular case they had to do the best they could to use single and twin. They found a static discharge in the armouring unless it was well earthed every 100 feet. It was surprising to see this in practice. Unless it was specially earthed they could see a spark off the outer armouring. It was very unwise to use single armoured cable or twin, unless it was well earthed.

They had a variety of switchgear at the collieries, and he would like if possible to get all the good points of the various types combined: they would then have a really good switch. In H.T. gear they found that the new regulation coming into force compelled them to earth the circuits when isolating the switch. He thought that some of the makers should allow a greater space between the contacts, as it was quite possible, even if the switch had been isolated, for a current creepage to occur from the live side. In several cases they had very heavy tanks, which were awkward to handle: the makers could remedy this difficulty and place the tanks in such a way that it would be possible to screw them down and take them out when overhauling. Another thing they found was that the internal parts of the switch were cramped, and he thought the makers would be well advised to come underground and see the actual jobs. These things should be constructed in such a way that repairs could be carried out easily.

Mr. Thomas also said that it took an expert to understand some of the tripping devices they had at the collieries: he did not believe in these intricate tripping devices but considered they could get a plain simple device that would work just as well. Another thing he had noticed lately in all switchgear, H.T. and L.T., was that they were made of all metal, and he thought it would add to the safety in general if they had insulated handles fitted.

Regarding the standardisation of motors, he quite agreed with Mr. Rutter; they had standardised their motors at the mines with which he was connected. They were thus able to get a motor down to replace a breakdown, without much trouble. Without standardised motors it would mean drilling fresh holes and carrying a lot of spare material. He believed in the standardisaton of swtchgear, motors, and control gear, as time was thereby saved and the colliery freed from lengthy stoppages.

Mr. COPE.—Mr. Rutter evidently did not like oil break gate-end switches: personally, he (Mr. Cope) swore by them. They had a series of five gate-end boxes working a longwall face; they were oil immersed and very portable. On the other hand, coming to controllers, they had just installed an air-break controller on a 350 H.P. haulage, and it was working beautifully. As Mr. Yates had said, there was no difficulty at all in getting a circuit breaker to work in oil. Some years ago, full of enthusiasm with the results of this circuit breaker, he (Mr. Cope) unfortunately installed an oil-immersed controller on a 500 volt D.C. system, and the results were rather uncomfortable.

The question of trailing cables at a longwall face working coal cutters was a very important one, and he did not think that the final method of insulating the cable had yet been reached. There were many difficulties in the way, and from Mr. Horsley's Report they would realise that trailing cables were very susceptible to damage. Mr. Cope thought that the method suggested by Mr. Horsley, in which wire armouring was incorporated with the outer layer of cab tyre, would meet the case. They had tried the ferflex braiding which Mr. Rutter had touched upon, and found it was far more trouble than it was worth.

Mr. STANAWAY.—The cable question had been gone into at some length by Mr. Rutter, but each type of cable has its own particular advantages and the ultimate choice depended on the local conditions. Mr. Thomas had mentioned the use of cab-tyre cable for telephone work but he, Mr. Stanaway, would recommend as the most suitable cable a rubber insulated S.W.A. and braided cable. Again, Mr. Rutter had mentioned the use of brattice cloth round the wire armouring, but that was a dearer method than having the armouring braided and compounded overall in the first instance. Too much stress could be laid on the seepage or drainage of paper cables. When the cable end is open there is a tendency for the compound to drain out, and care should be taken to fill each joint without delay. In regard to faults, Mr. Stanaway thought it would be good practice to have some system of tracing the history of the cable or the joint which may have failed, a record, so to speak, from its birth to its casting off. Mr. Rutter had also remarked that perfection in the making of joint boxes had been somewhat marred by the use of cast iron cases, but he could not quite agree, as the amount of possible damage was not so great as the author imagined. If Mr. Rutter would go a little more closely into the question he would find that the best makers of these boxes were using malleable iron glands instead of cast iron, and the possibility of breakage would be to a great extent eliminated in future.

Mr. R. H. DAVIDGE said, referring to earthing the switch, that there was such a switch on the market to-day, used in conjunction with condensers. It was quite essential when breaking the circuit that you should earth the condenser. With regard to fractures in lead, he referred to a paper read before this Association at Cardiff some years ago by a representative of one of the cable firms. In his opinion single core A.C. cables should never be used.

Mr. RUTTER, in reply, thanked the members for the way in which they had received his paper. Answering Mr. Yates re the fracturing of the lead cover of cables, he said he had only seen one or two photographs, and the slide he had shown on the screen was one illustrating the various stages of development of damage to a cable buried beneath a roadway, and subjected to vibration set up by the pounding of heavy traffic. As to Mr. Thomas' remarks about cab-tyre cable, he said the original cable was a rubber, hemp insulated S.W.A. cable. The trouble with cab tyre sheath cable was that the elasticity of the cab-tyre was greater than that of the copper conductor, with the result that if a sudden weight, due to a small fall, should come on the cable the copper conductor might give way and the outer cab-tyre sheath return to its normal position, leaving a troublesome intermittent break inside a perfectly good sheath.

In reply to Mr. Stanaway regarding the use of brattice cloth, he would say that this was only put on owing to damage done to the cable during installation. The number of men was limited, and part of the braiding was rubbed off; finding that the armouring was beginning to rust, they put this brattice cloth on as a repair.

Mr. Jarrett had emphasised the point of solid lead sheath joints. They saw that done for practically all joints for municipal work, but all mine electricians would like a few loopholes to get at faults.

With reference to oil immersed controllers, the secret of reliability was frequent inspection.

SOUTH WALES BRANCH.

Annual General Meeting.

The annual general meeting of the South Wales Branch was held at Porthcawl on Saturday, May 18th, a large number of members and friends from all parts of South Wales journeying by car to the popular seaside resort. The party assembled for tea and the retiring Branch President, Mr. T. S. Thomas, presided at the meeting which followed. At the outset Mr. A. Bremner and Mr. W. J. H. Porter were appointed scrutineers of the ballot for four new members of the Branch Council.

Mr. H. J. NORTON, Hon. Secretary, in his annual report said that although the Branch retained the premier position in the Association in regard to the number of members, the nett result was not so satisfactory as in the previous year. At March 31st, 1929, the membership of the Branch was 396 (patrons 3, members 267, associates 86, and students 40). Fifty-seven new members were accepted during the year. With reference to the Examinations 17 candidates had sat and the following certificates were awarded:—

Messrs. G. Phillips (Honours), B. S. Chaloner, C. H. Davies, I. Elkins, W. E. Richmond, C. H. Tucker, A. J. Venables, William Williams and J. Vaughan Harries (firsts), C. E. Constable, C. L. James, T. G. Price, W. J. Sansom, E. Thomas, William Trenhail and W. F. J. Twitt (seconds).

Eight meetings and one extraordinary general meeting were held during the session, and visits were paid to the South Wales Power Coy.'s Generating Station at Treforest, the Edison Swan Cable Works at Lydbrook, the Cardiff Engineering Exhibition and the E.C.C. Works at Wolverhampton. The meeting on the 18th December, 1928, was a joint meeting with the Colliery Managers' Association with whom, it was pleasing to note, a very friendly feeling existed.

The extraordinary general meeting was in connection with the Qualifications of Colliery Officials Departmental Committee of the Mines Department.

The Paper by Mr. E. F. Cope, Pontardulais, entitled "A Comparison between Power Supplied in Bulk and Private Power Supply at Collieries" was awarded the Branch Prize of £2 2s. 0d.

The Hon. Secretary appealed to members eligible for branch prizes to read papers before the Branch. Members did not appreciate the fact that the Association granted substantial prizes for the best papers read during the session, and the Branch itself also offered prizes to eligible members, i.e., those members or their subordinates who signed the log book. It was papers from this class of member which the Branch particularly required, as they gave the practical views of the men who handled the plant, and the experience was that this class of paper always created very full and valuable discussions.

In conclusion the Secretary appealed to members to do their utmost to increase the membership of the South Wales Branch in order to maintain their position as premier branch of the Association.

Mr. IDRIS JONES, in moving the adoption of the Report, paid a tribute to the efforts which had been made by the Secretary.

Mr. W. W. HANNAH seconded the adoption of the Report, which was carried unanimously.

Mr. A. C. MacWHIRTER, Hon. Treasurer, then presented the Balance Sheet and dealt with the various items in detail. It was unfortunate, he said, that members who wished to resign did not notify the Secretary; their omission to do so rendered the Branch liable to headquarters for the proportional subscription. It was a credit to the Branch and to Wales that they had the largest number of students of any branch in the country. They were doing pioneer work, and he was of the opinion that the amount payable to head office for the student members should be reduced. Everything possible should be done to encourage the Branch in its efforts to introduce student members.

The report was adopted on the proposition of Mr. Dawson Thomas, seconded by Mr. C. F. Freeborn.

Mr. E. D. C. OWENS, Hon. Secretary of the Western Sub-Branch, said he was pleased to report that the sub-branch continued to show an increase in membership in spite of the difficulties experienced in the district during the past three years. The membership was 102. The programme for the past session had not been fully carried out owing to the illness of two authors of papers and other unforeseen conditions which necessitated the cancellation of meetings. In spite of these difficulties, however, the meetings which had been held were well attended and general interest was maintained.

THE CHAIRMAN commented on the satisfactory progress which was being made by the Sub-Branch, which he said reflected great credit on the energetic work of the Hon. Secretary and the other officials.

The report was adopted on the proposition of Mr. A. Bremner, seconded by Mr. S. T. Richards.

Election of Officers.

The following officials for the South Wales Branch were elected for the coming year: Branch President—Mr. W. W. Hannah, Tredegar; Vice-Presidents—Sir Arthur Whitten Brown, K.B.E. and Mr. W. Roberts; Hon. Treasurer—Mr. A. C. MacWhirter; Hon. Secretary—Mr. H. J. Norton.

The ballot for four members of the Council resulted in favour of Messrs. J. B. J. Higham, Treforest; F. E. Pring, Pontypool; H. Pritchard, Aberaman; and G. Probert, Abercarn.

Mr. W. W. HANNAH proposed a vote of thanks to the retiring Chairman.

Mr. T. S. THOMAS, in reply, said his year of office had been a very eventful one and he had received every possible support from the Hon. Secretary, Hon Treasurer and members of the Committee as well as the majority of the members of the Branch. Although the year had not been particularly successful in regard to increase of membership, the right type of men were members, and that was what was required in an Association such as theirs. In the coming year there were many momentous questions coming forward, especially regarding the Qualifications of Mining Electrical Engineers, but he felt that these important matters could be left with safety and confidence in the hands of their new Branch President, Mr. Hannah.

LONDON BRANCH.

Research and Progress.

JOHN W. ROBINSON.

The following is an abstract of the inaugural address delivered by Mr. Robinson, as President of the London Branch, on November 21st last. Reviewing the important question of scientific progress, Mr. Robinson alluded to the Safety in Mines Research Board, which had made such considerable progress in various directions. During the year ended 31st March, 1928, an amount of £52,718 was expended on research work (apart from the building of research stations). During the year 1927, the Research Board published eleven papers dealing with the results of research work, and other results were contributed by the investigators to various scientific and technical journals. This method of disseminating the knowledge so obtained had evidently proved a want, as the Board were considering the question of how best to spread the results of the researches amongst those engaged in the mining industry.

Already certain suggestions had been formulated in the way of arranging popular lectures by qualified persons in each coalfield, with experimental illustrations each dealing with a phase of particular research.

The scheme of co-operative research with the United States Bureau of Mines had matured on satisfactory lines, and Mr. Robinson said he believed we could look forward with some degree of anticipation of co-operation in research also extending to Belgium, Germany and France.

In industry, particularly mining, the opportunities of research and experimental work were of primary importance, and we, unfortunately, were perhaps apt to look upon this research work as the exclusive privilege of the technical colleges and scientific institutions. That, however, was not the case. A little reflection would show how small in fact is our knowledge of the subjects engaging our daily attention in every sphere of activity.

Progress, clearly, could only be accomplished by diligent and constant research. Whilst such efforts of co-operative research render valuable aid, they should not be developed at the expense of stamping out individuality, which always contributed so greatly to success in every field of endeavour.

The members of the Association of Mining Electrical Engineers with their scientific and practical training had the privilege and opportunity, more than in any other sphere of activity, of paving the path to progress and prosperity in concentrating attention on research and experimental work. They should keep abreast of every improvement in design and method by joining freely in technical discussions and by reading technical journals and literature. A man with an open receptive mind would in the long run beat a more clever man who thought he had nothing to learn.

We had heard a great deal of trade secrets in the past. Could a truce be called in this direction by fostering the free exchange of ideas and co-operation of rival firms in the same industry? In a large measure this exchange of confidences could be attained by amalgamations. Such understandings, however, should not be used for price maintenance, otherwise the fostering of any particular trade on a legitimate and competitive basis would be defeated.

It had been established that the maintenance of fixed, or monopoly, prices was disadvantageous both to the consumer and the producer; it has the tendency of destroying the individual initiative of producing Companies, and inevitably resulting in inefficiency.

Mr. Robinson, whilst dealing with the subject of amalgamations and co-operation, referred in passing to the elimination of waste: it could not be denied that there was room for improvement in that direction. In the race for progress there was always a line of least resistance and a tendency to slip into wasteful methods. In many instances this wastefulness continued until the time arrived when stern facts had to be faced; that often resulted in drastic cuts and economies which were not given the requisite careful consideration and which really amounted to "uneconomic economies." It was false economy to imagine that spasmodic attention to cutting out waste would in the end be successful. This subject should have careful and constant attention, and it was pleasing to learn that some firms had considered the need for making economies to be of sufficient importance to appoint an executive member of the staff to devote the whole of his time and energies in that direction.

It was alarming to note the amount of money and time expended in litigation on questions which might be amicably settled by arbitration. That system should also be adopted for settling industrial strife; the extent of waste arising from industrial disputes between employers and employees needed no elaboration. Then there was the disinclination to incur expenditure that was not of a visibly productive character; evils were allowed to continue because of the expense to remedy them. Improved methods of working involving an addition to working costs were vetoed unless it could be demonstrated that they would immediately produce better financial results, although there might be very strong reasons on other grounds for their introduction.

The scientific use and treatment of coal was dealt with by Mr. Robinson in a broadly critical manner. Pulverised fuel firing; the scientific control of boiler plant; the scientific treating of coal by means of low temperature carbonisation were all of vital interest by reason of the great possibilities they opened up for a coal producing country like our own. For a long time there has been a great divergence of opinion between the two schools of thought in the carbonising of coal, namely, those who believe in high temperature and those who advocate low temperature. The exponents of both systems have long stressed their respective claims. Extraordinary interest was being centred in the development of low temperature carbonisation, and the situation could be regarded as satisfactorily progressing and must lead to important results in the near future. It had been suggested that the drastic remedy for revitalising the mining industry was the adoption of low temperature carbonisation by collieries on the largest possible scale within the limits of their financial resources, and that by installing carbonising plants and extracting all the valuable byeproducts now wasted, the coal owners would find their coal quickly enhanced in value and the collieries no longer losing concerns.

Mr. Robinson said he believed that as a result of the large scale experiments and development of low temperature carbonisation we could look forward to a new era in the mining industry; not only the coal owners but other industrialists also were waking up to the possibilities and they would not shelve their responsibilities in this progressive direction.

Referring, in conclusion, to the affairs of the Association, Mr. Robinson expressed the hope that members would not hesitate to bring forward papers, and to open discussion on points of interest. The success of the Association was entirely dependent on the active interest of each individual member. Experience had demonstrated that in the preparation of papers, the authors probably reaped greater benefits than they conferred. The marshalling of facts, the verifying of observations and the presentation of conclusions were healthy exercises and, lastly, the criticism of them was a clarifying process. The Association had already a good membership, but there were still many eligible men to be encouraged to become members.

Manufacturers' Specialities.

The Manufacture of Electric Motor Control Gear.

The British Thomson-Houston Co., Ltd., has for many years specialised in the manufacture of electric control gear, and is well in the forefront with standardised control gear improved in the light of practical experience. The Company published its first price list on Rugby built motor starters in 1902, and supplied the first contactor equipments to the London Underground Railways in the same year. It is claimed that the B.T.H. Co. was the first to introduce contactors for industrial applications, and installed the first equipment of this kind at the works of Scotts Shipbuilding and Engineering Company at Greenock, in 1910.

The building shown in Fig. No. 1 forms a part of the main works at Rugby and is entirely devoted to control gear. The tinsmiths, press shop, foundry, and the sections dealing with resistances, insulation and coil winding are situated in other buildings. In the factory illustrated the machine shop occupies the whole of the second floor, with an area of 22,500 sq. feet. It is thus situated between the two floors on which the majority of the assembly work is done, the parts for the smaller apparatus being sent up to the top floor, while parts for the larger types of apparatus go down to the first and ground floors.

Fig. 1.—The Control Gear Factory.

The ground floor is used for the assembly of contactor panels, automatic sub-station panels, transformer tap-changing "on load," and ship propulsion equipments: also flame-proof mining type contactor and other control gears. In the bus-bar section of this floor are special tools for the edgewise bending, drilling, forming, cutting and sweating of bus-bars. This enables bus-bars and heavy current back connections to be made neatly, and with few joints.

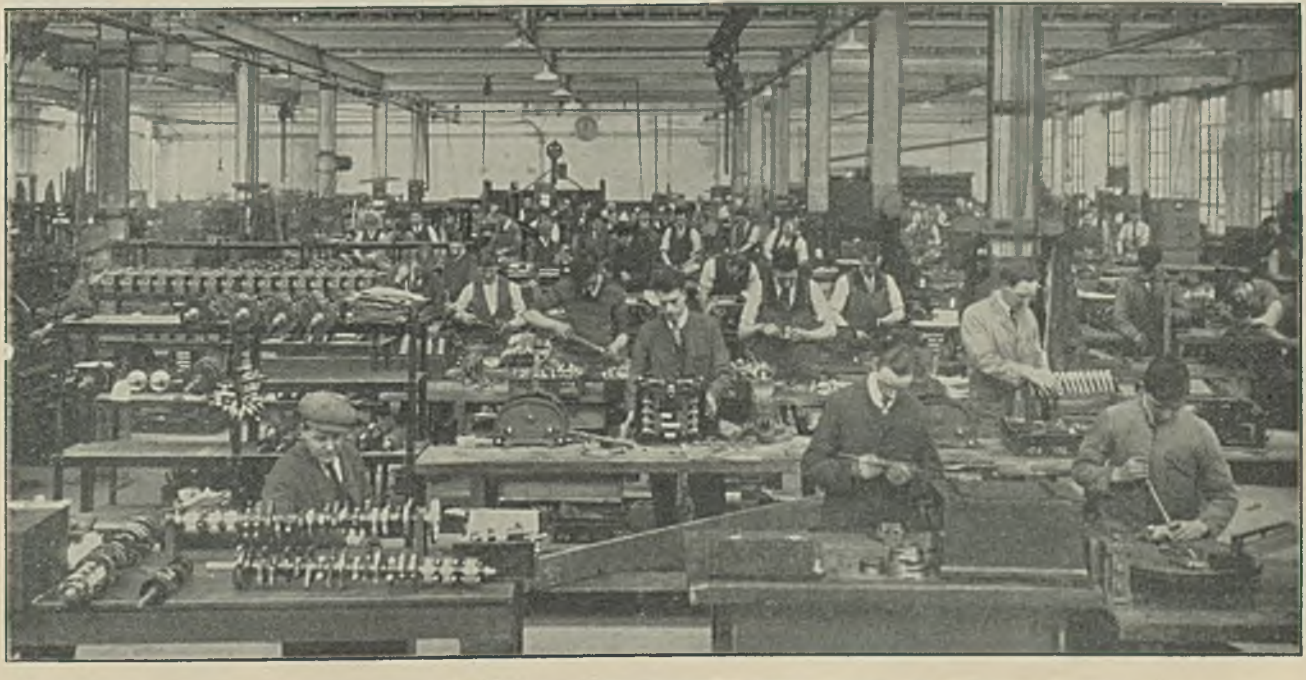

Fig. 2.—Assembling Controllers, Hand-operated Starters, Pillar Starters; also Winding Resistance Tubes.

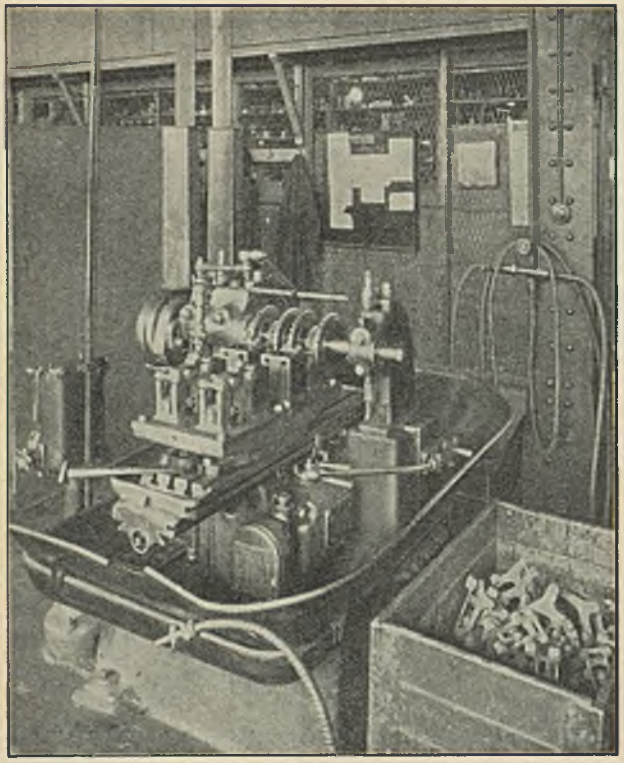

Fig. 3.—Milling Operating Arms for Contactors: Index Table Method.

The first floor is devoted to smaller contactor panels and to traction equipments, etc., and the second floor is the machine shop. Here are many interesting and ingenious devices and machines specially developed for quantity production of the many peculiarly shaped parts which are common to control gear. This floor has been laid out with a view to keeping the material flowing continually in one direction. Raw material enters by a lift at the North end, and the finished part is finally delivered to the inspection department at the South end, where a second lift carries it to the assembly section. On the assembly floors the material flows in the reverse direction, i.e., South to North, thus giving the material a uni-directional flow throughout the building.

The top floor, a general idea of which can be obtained from Fig. No. 2, is devoted to the assembly of controllers, hand starters and pillar type starters, and the winding of resistance tubes. The resistance tubes for starters and field rheostats are in the form of vitreous enamelled units, wire wound on porcelain tubes and then enamelled in an electrically heated oven, the temperature of which is automatically kept within certain predetermined limits: the temperature is continuously recorded on a chart. This plant is capable of turning out 9000 resistance tubes per week. The units are enamelled at red heat and on completion will withstand overloading to similar temperatures for comparatively long periods, without permanent injury. As the wire is coated with a thick glaze it is impervious to moisture, and this is undoubtedly the ideal construction for high resistance units.

An important product of this floor is pillar type starters, both A.C. and D.C. Both faceplate and drum-type starting pillars are manufactured. D.C. pillars, comprising drum type starter with step-by-step ratchet

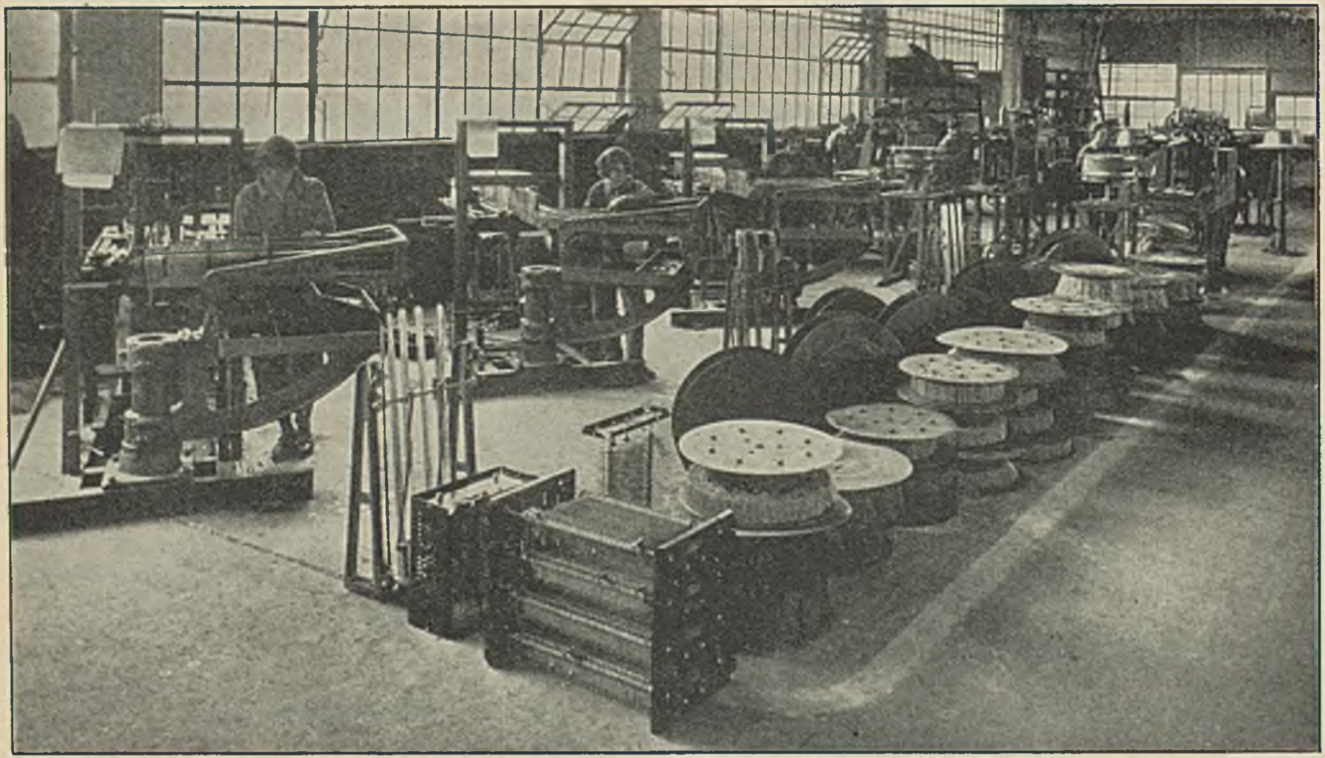

Fig. 4.—Winding and Assembling Unbreakable Resistances.

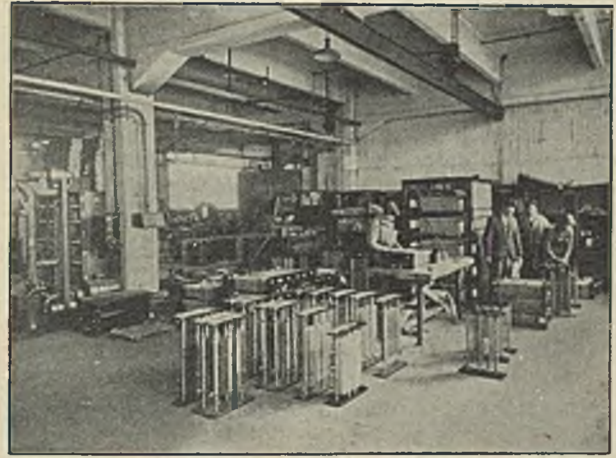

Fig. 5.—Finishing and Testing Unbreakable Resistances.

motion are supplied, up to 1200 amp. capacity. A.C. pillars, equipped with a similar drum-type starter for the rotor circuit, and a triple pole contactor with overload relay in the stator circuit are supplied up to 500 amps. per phase. D.C. faceplate starters, owing to the greater quantities required, necessitate special handling by the straight assembly line method, starting with the switch base at one end and finishing with the complete starter at the other. The number of operations to be performed by each worker is planned to occupy the same time, so that there is no accumulation of work between the operators. The necessary parts required for each operator are stored in suitable receptacles, so that they are handy to the operator with a minimum effort. At the end of the line the complete starter is tested and is ready for packing and despatch.

Fig. 6.—Assembling Drum Controllers.

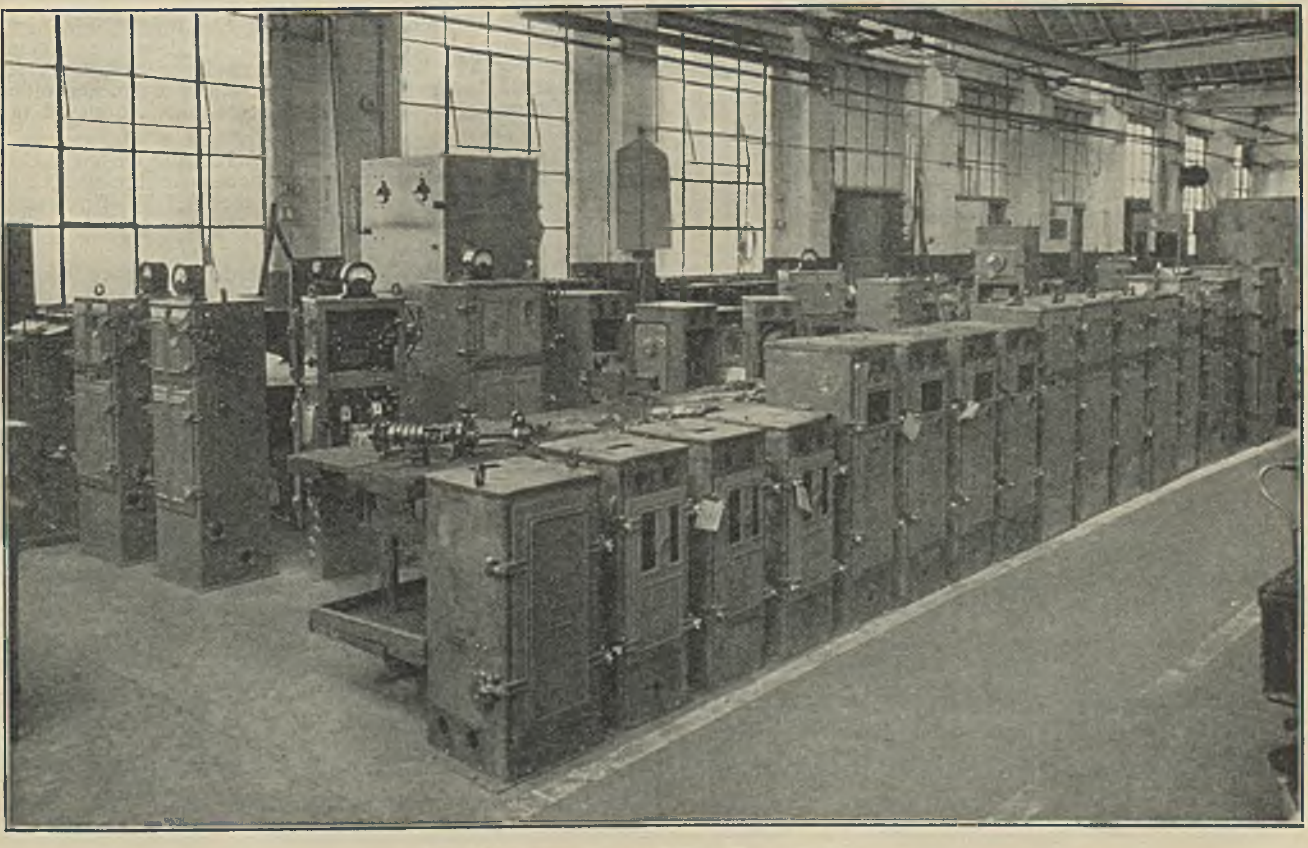

Fig. 7.—Assembly of Pillar Type Starters.

Cast grid and unbreakable resistances for mining controllers, crane controllers, trolley buses, tramcars, traction, neutral earthing, etc., are made in a separate building. The machines for producing and assembling these unbreakable resistances are shown in Fig. No. 4. The units are completed by fitting terminals and assembling in frames, after which they are subjected to a final test. The unbreakable resistance is composed of a continuous wire unit, formed into grids on the machines seen in the illustration. The wire, or strip, comes into the works in a continuous coil. It is first cleaned and then electro-plated, to render it proof against corrosion. Then it is fed to the grid-forming machine, from which it emerges as a continuous series of grids, which are coiled directly on to drums. The next operation is that of building the grids into resistance banks, mounting on mica insulated tie rods with the necessary spacing and insulating washers, and then passing the product to the next section where terminals and covers are fitted. If necessary a number of boxes are bolted together to form a complete unit. They are finally tested for resistance and insulation.

The continued advance of electricity into fresh fields, and the improvements in the machinery which other branches of engineering are continually making, as a result of such application, daily brings forth new problems and requirements in regard to control gear. This necessitates the employment of a considerable staff of engineers and draughtsmen, and important large sections of the drawing office are devoted entirely to control gear. The engineering staff is in a separate office, and each individual specialises in some particular branch of design or industrial application, such as D.C. starters, A.C. starters, resistances, contactor gear, pillar type starters, controllers, automatic sub-stations, traction, ship propulsion, colliery winders, rolling mills, etc. Switchgear of the central station type is not handled in the Rugby works, this being the product of an entirely separate factory at Willesden.

Colliery Men Visit Cable Works.

The photographic group reproduced below was taken on the occasion when members of the Lancashire and Cheshire Colliery Officials and Staffs' Association recently visited the Prescot Works of British Insulated Cables, Ltd. The party, which numbered 160, included Mr. J. Nuttall, of Wigan, President of the Association, and Mr. Thos. Halstead of Bolton, Secretary.

The whole of the factory was thrown open to the visitors and a large number of guides, including some of the principal officials of the Company, conducted the visitors through the departments and explained the various manufacturing processes.

A somewhat strenuous two hours' tour of the works, which the visitors saw something of copper rolling, wire drawing, cable making, and the manufacture of accessories, was followed by tea in the staff lunch room.

Members of the Lancashire & Cheshire Colliery Officials and Staffs' Association at the B.I. Works, Prescot.

NEW CATALOGUES.

GENERAL ELECTRIC Co., Ltd., Magnet House, Kingsway, London, W.C. 2.—The Installation Leaflet No. 8 is a detailed description of the complete electrification of the Barnstone Cement Works, Nottinghamshire.

BRITISH ALUMINIUM Co., Ltd., Adelaide House, King William St., London, E.C. 4.—A useful and interesting handbook has been produced by re-printing, with many illustrations, a Lecture given by Mr. Edgar T. Painton, B.Sc., before the Rugby Engineering Society, entitled "Aluminium, its Production and Application." The subject is well covered in the technical way as well as in an attractive style.

ENGLISH ELECTRIC Co., Ltd., Queen's House, Kingsway, London, W.C. 2.—Three new publications of the E.C. Company deal respectively with "English Electric" Power Equipment for all Industries, Fullagar Oil Engines, Truck-type Switchgear.

BRITISH INSULATED CABLES, Ltd., Prescot, Lancashire.—An illustrated leaflet of particular use to mining men directs particular attention to the highly flexible trailing cables the "Pliable Armoured Cables."

Prescot Welders, Cab Tyre Sheathed Cables and Flexibles, "Copperweld" (a high-tensile tough steel core with an outer heavy layer of pure electrolytic copper welded thereto), a pocket-folder Wireman's Guide—are all recent publications of the B.I. Co.

AUTOMATIC TELEPHONE MANUFACTURING Co., Ltd., Strowger Works, Liverpool.—A high-class, art-printed catalogue describes the A.T.M. Fire-alarm apparatus, open and closed systems and the firemen's call-bell system.

BROOKHIRST SWITCHGEAR, Ltd., Northgate Works, Chester.—The leaflet No. 287 gives details of a flexible design of starter which the Company have for use with change-speed squirrel cage motors. No matter what arrangement of starting is required on the various speeds, the requirements can be met by a simple oil immersed starter similar in appearance to a standard single-speed A.C. control gear. The starters described are suitable for two-speed and three-speed arrangements.