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EDITED BY E. DINSDALE PHILLIPS.

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Aluminium for Mining Services.

Readers will recollect that last year we had occasion to refer to the International Competition organised by the great aluminium firms. Substantial prizes were offered for information and suggestions which would provide industrial outlets for the illimitable supplies of aluminium. An abstract of the more valuable entries submitted for the competition has now been published and interesting as it undoubtedly is in shewing the immense field already providing scope for this metal and its alloys, it is none the less evident that vastly greater possibilities remain to be explored.

In this connection it is significant to note that in the opinion of the judges no entry was of sufficiently outstanding merit to justify the reward of the full amount offered as first prize. The winning position in the list of awards is taken by a paper which submits item by item the proved and possibly still greater advantageous uses of aluminium and its alloys throughout the fine leather dressing and skin dyeing industry, and more particularly in connection with glove making.

When one comes to consider the territorial limitations and the aggregate weights of machinery used in this specialist trade it becomes more or less automatic to cast the mind over the potentialities of the mining industries of the world which are wide in extent and which are dependent upon large quantities of heavy machinery. Moreover, the general conditions of mining are peculiarly those which invite a wholesale substitution of aluminium. Its resistances to corrosion, its light weight and its advantages of accurate machining, whereby sub-dividing heavy plant units, for transport over rugged country and through confined spaces, and the provision of duplicates introduces no manufacturing or operating difficulties.

Turning to the published abstracts of entries it is rather surprising to find how little the electrical field has produced competitors. To mention such suggestions as the use of aluminium for lighting reflectors, light weight accumulators, overhead line poles, aluminium sheathing for cables, details in turbo-alternator construction, is practically to exhaust the electrical list. It would appear, therefore, that here is practically a virgin field of opportunity for the enterprising mining electrical man to achieve something well worth while in an interesting manner. The engineer of a large modern colliery might well, for example, follow the lead of the glove leather competitor and, if his entry were done so completely as that which won the reduced premier award last year, the value of the prize would doubtless in his case be greater because of the tonnage outlet which, after all, is the sole desideratum of the competition.

The rules governing this year's competition are published at length in this issue and for immediate information anyone interested should get into touch with the British Aluminium Company who are the publishers of the abstracts of entries of last year's competition and who also have available many other technical and general publications which obviously must be of indispensable value to intending contestants.

The A.M.E.E. Summer Convention.

Is there any member of the A.M.E.E. who is not wholly satisfied with the arrangements planned for his benefit and enjoyment at the Annual Convention to be held in Glasgow, June 20th to 25th? If so he must be a very difficult man to please. The full programme is now available and is published at length on page 379. It shews an exceptionally successful blending of the utilitarian with the pleasurable and is greatly to the credit of the committee men of the West of Scotland Branch. Apart from that acknowledgment due to these services so generously given by their colleagues, members generally will be disposed to a feeling of deep satisfaction in knowing that their Association has been able to draw to itself and its interests such a widespread circle of sincere and influential friends from outside its own ranks.

This co-operation of the Association with mines owners, engineers and manufacturers, whilst altogether pleasing from the personal point of view, is surely bound to be productive of much good in regard to hard business policies and in smoothing away obstacles from the path of industrial progress generally.

It only remains now to impress upon members the extreme importance of attending the Convention if at all possible, and to urge those who do propose to be present to lose no time in getting into immediate touch with Mr. W. G. Gibb, the organising secretary: remembering that the ultimate and complete success of the meeting depends upon early definite assurances of attendance.

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. 2; York Street, Manchester; 1 St. Andrew's Crescent, Cardiff; 120 George Street, Edinburgh; or 15 Donegall Square, W., Belfast.

Mines Department.—REPORT OF H.M. ELECTRICAL INSPECTOR OF MINES for the Year 1930. Price 6d. nett.

Mines Department.—Report of the Circumstances attending the Explosion which occurred at the NEWDIGATE COLLIERY, WARWICKSHIRE, on the 3rd September, 1931, by Sir Henry Walker, C.B.E., LL.D., H.M. Chief Inspector of Mines. Price 6d. nett.

This Report is of particular importance to mining electrical men in that it contains much valuable information given in the evidence concerning the possible means of igniting the firedamp. The probabilities centred around a broken electric lamp bulb, an electric plug connector and a damaged flame lamp. The final summing-up reads as follows:

"The only other means of ignition suggested was arcing in the plug connector of the conveyor motor. This was the suggestion of Mr. Rowley, and on examination of this connector by Mr. Horsley on the day following the explosion it was plain to him that arcing had been taking place between the top pin and its socket. The effect of this arcing was also seen at a later date by Mr. Mackay, the maker's representative, who said no claim was made that the connector was flame-proof."

"Having considered the whole of the evidence, I have come to the conclusion that firedamp was suddenly ejected from the waste by a heavy fall and that an explosive mixture was formed in the top end of 6's face and there ignited by arcing in the plug connector of the conveyor motor."

"(1) Although it would be difficult under present requirements to say that the use of the plug connector in such a place as 6's face was illegal, connectors which are not flame-proof even in abnormal circumstances, such as arcing between pins and sockets, should not be allowed in any part of a mine to which General Regulation 132 (i) applies. In fact, I consider it desirable that none other than flame-proof connectors should be used in any mine."

"It is to be remarked that in the Newdigate Colliery, those connectors, which were not rated as flame-proof, were at the time of the explosion in course of being replaced by others which were flame-proof, and three only remained to be changed."

"(2) It would be better when possible to have motors driving face conveyors placed at the intake end rather than at the return end of a face."

"(3) The flame lamp (No. 680) of Samuel Wright was found after the explosion to be defective in that four of the pillars had come away from the top or middle ring of the lamp, thus weakening the general structure so that the framework was no longer rigid. The fractured ends of three pillars appeared to be old, that of the fourth had a new appearance."

"There was no suggestion that this lamp was the cause of the explosion, but as the pillars of a lamp may be pulled away from the middle ring, or fractured within this ring, by the constant screwing up of the glass retaining ring, it is very necessary that the attention of lamproom attendants should be called to this possible defect."

Mines Department.—COAL MINES ACT, 1911: REGULATIONS AND ORDERS RELATING TO SAFETY AND HEALTH, 1932 Edition (revised to 31st December, 1931). Price 1s. 6d. nett.

The regulations and orders of a general nature, which were in force on the 1st January, 1932, are collected together in this volume in a convenient form for the use of mine officials and others concerned with safety and health, in mines. The book also contains lists of permitted explosives and approved safety lamps, safety lamp glasses, breathing apparatus and smoke helmets, as well as memoranda dealing with firemen's certificates, the storage and test of explosives and the test of safety lamps and rescue apparatus.

DIELECTRIC PHENOMENA: III, BREAKDOWN OF SOLID DIELECTRICS by S. Whitehead, M.A., Edited with a Preface by E. B. Wedmore, M.I.E.E., F.Inst.P., Director of the British Electrical and Allied Industrial Research Association. London: Ernest Benn Ltd., Bouverie House, Fleet Street. Price 30s. nett.

"PLEASE QUOTE."

By "Estimator."

Few orders for materials or plant are placed without enquiries having been sent out and the resulting quotations compared. When the requirements are in the nature of raw materials comparison of the prices tendered usually reveals close similarity. When, however, manufactured articles complete in themselves are wanted, or an assembly of such articles to effect some particular purpose, the prices and specifications received not infrequently differ very widely. Why?

Amongst possible reasons for the great diversity of prices may be those due to makers' standard designs; in the case of electrical machine ratings, for instance these are graded differently by different makers and the maker with a standard size most closely approaching the size required, is enabled to put forward the cheapest offer On the other hand several firms may be in a position to offer precisely similar gear and yet their respective quotations differ very considerably; in such cases the reason for the widely varying offers may usually be attributed to the form in which the enquiry was issued.

Strange though it may seem, enquiries which state clearly what is wanted and also give a sufficiency of pertinent detail are not by any means in the majority, and too frequently an unnecessary amount of assuming otherwise guessing, has to be done by the estimator before all the details of the estimate can be decided upon and a tender sent in.

The enquiries which raise doubts in the minds of estimators can be roughly divided into two classes, those which do not give sufficient detail and those which give too much. These two classes usually emanate from two distinct types of buyers who may be grouped respectively as owners, working engineers and non technical buyers, and charge engineers, either on the staff or specially retained.

Let it be at once said that many enquiries issued by engineers are models of clarity and leave little, if any, room for ambiguity; also, that the comprehensive specifications issued by the leading firms of consulting engineers for large installations are not under comment. Large contracts by their nature and size entail a vast amount of work before a detailed specification with drawings can be issued and, these having been prepared from a full and accurate knowledge of what is wanted, but little variation therefrom is possible.

The enquiries which arouse doubts through paucity of detail are frequently clear in so far that they generally make known what is wanted but omit essential details, with the result that the estimator has either to write requesting additional information or to make assumptions based on experience. Moreover, there is always the attendant risk that, assumptions having been made and put forward an order results, the gear is supplied and then, upon being put into commission, trouble arises with the gear and, automatically, very shortly afterwards with its maker. An investigation is made and it is discovered that some important fact has not been disclosed to the supplier, information which if stated in the enquiry would have ensured the offer and supply of the proper apparatus.

To take a very simple example, it is insufficient to request a price for a 50 h.p. starter, for obviously particulars of the electricity supply are necessary; but equally important are the type of motor, i.e. nature of the windings, and the conditions and frequency of starts, and in a lesser degree the type of cables being run and the nature of the locality or situation in which the starter has to be installed. Yet rarely is all this simple information given in an enquiry.

The trouble is that the user knows what he wants quite well in general, and frequently in detail also, but he does not condense his knowledge and give it shape in words. Therefore, thought transference failing to function, much time and consequently money is wasted in an endeavour to imagine what exactly is wanted, and the most expert guesses based on the widest of experience, cannot be guaranteed always correct.

The opposite extreme is reached by those enquiries which give a wealth of detail, information not to be despised but embarrassing by reason of the impossibility of compliance by more than a few, or perhaps only by one, of the firms tendering. A user's specification of the gear required based upon general characteristics as indicated by the design of the leading manufacturers of such gear does not go far wrong, but a specification based upon the design of one manufacturer and embodying points to be found only in that gear prohibits all other makers from submitting competitive tenders. It is a waste of time for those other makers to prepare an estimate, and in effect the open enquiry is nothing of the sort but merely a request to one firm only. The ultimate result is that the one firm is given an open order at an easy price restricted only as being reasonably within the market limits.

Another type of enquiry to raise doubts in the mind of the estimator is the one containing particulars which, considered in relation to one another, do not conform with usual practice. Such an enquiry may be perfectly sound but the estimator must quote his best price for gear to do the job satisfactorily, and without knowledge of the actual conditions he wisely avoids undue risk. If he is confronted with an enquiry for say, a 300 amp. circuit breaker with an ammeter scaled 0/350 and trip coils for 125/250 amps., he wonders just what he should put forward and, incidentally, what the other fellows will put forward also. In these days of lean business and keen prices an estimator is of necessity a super-optimist, always hoping for the best and stifling his fear of the worst, whether he gets the order or loses it.

Granting that the enquirer knows what he wants, probably what he expects to pay, and realises that he will get no more than he will pay for, it should be an easy matter for him to frame his enquiry so that it states exactly what he wants to do and leave it to the manufacturers to settle the details. If information additional to that given in a tender is desired it is usually readily forthcoming, the makers being every ready to use any opportunity for increasing their chances of the order by negotiation and service.

By stating "what he wants to do" is meant that the enquirer, rather than arbitrarily selecting some size or rating, should state the actual power required, current to be carried, or work to be performed, together with the possibilities of later developments, and responsible makers can be relied upon to offer that which is suitable. To obtain a figure and then ask for something a bit bigger is a hit-or-miss method and can easily result in unnecessary expenditure or inefficient service. If such boosting is the result of some unhappy experience and is intended as a safety factor it should be remembered that British Standard Specifications are safeguards to the user and maker alike; also that mining equipments to meet the conditions prevailing in mining work are highly specialised lines best entrusted to firms who have the experience resulting from long associations with mining problems.

Because drawing up a specification is something of an art, it is no reflection on the abilities of many good men to suggest that, on the next occasion plant is required, instead of merely giving the barest details, or at the other extreme detailing a number of assumptions and arbitrarily arrived at values, it would be better to state the results it is wished to attain, and then special preferments, if any. Such an enquiry will contain the information essential to the preparation of an estimate, and the resulting quotation will be the best the manufacturer can put forward to meet the conditions stipulated. He will have full confidence in his offer, which cannot be the case when he only knows part of the story.

The Association of Mining Electrical Engineers.

ANNUAL CONVENTION IN GLASGOW.

21st, 22nd, 23rd, 24th and 25th June, 1932.

The West of Scotland Branch has arranged an interesting and instructive programme for the above Convention and the Council hopes that as many members as possible will attend in order to support their efforts and to make this as successful a gathering as previously.

Glasgow is the largest industrial city in Scotland, housing within its boundaries more than one-fourth of the total population of Scotland, and, in the British Isles, is second only to London. As a centre of Engineering and Shipbuilding it is second to none.

Through the kindness of the Corporations of Glasgow and Edinburgh, and the Clyde Valley Electrical Power Co., each visitor will be presented with a finely illustrated brochure of each City and also of the Hydro-Electric Power Scheme at Lanark.

Members desiring to attend the Convention at Glasgow, are requested to fill up and return the Form for Excursions, Dinner and other Tickets WITH REMITTANCE, not later than 7th June, (earlier if possible) to:

Mr. W. G. Gibb, Treasurer & Hon. Secretary,
63 Greendyke Street, Glasgow, C. 1.

The Grand Hotel, Charing Cross, Glasgow, will be the Headquarters during the Convention and a certain number of bedrooms have been reserved there and at other hotels. Private apartments can be reserved, if desired.

Correspondence may be sent either to the hotel at which members are staying, or to the Grand Hotel, Glasgow, Room No. 22, which has been reserved as Headquarters Administrative Offices. The adjoining Room No. 23 has also been placed at the disposal of visitors as a private Lounge.

Monday, 20th June.

Informal gathering will be held in the Grand Hotel, Charing Cross, Glasgow, from 7 p.m. to 9 p.m. at which light refreshments will be served. The Reception Committee will be in attendance, and visiting members will have an opportunity of making the acquaintance of local members.

Tuesday, 21st June.

ALTERNATIVE VISITS.

(a) 9-30 a.m.—Coaches leave Grand Hotel, Glasgow, for Anderson, Boyes & Co., Ltd., Flemington Works, Motherwell.
12-30 p.m.—Lunch as guests of Messrs. Anderson, Boyes & Co., Ltd.
2-0 p.m.—Coaches leave to join other parties at the Clyde Valley Hydro-Electric Power Station, Falls of Clyde.

(b) 9-30 a.m.—Coaches leave Grand Hotel, Glasgow, for Mavor & Coulson Ltd., Bridgeton Works.
12-0 noon.—Lunch as guests of Messrs. Mavor & Coulson Ltd.
1-30 p.m.—Coaches leave to join other parties at the Clyde Valley Hydro-Electric Power Station, Falls of Clyde.

(c) 9-30 a.m.—Coaches leave Grand Hotel, Glasgow for Mavor & Coulson Ltd., East Kilbride (Conveyor) Works.
12-0 noon.—Lunch as guests of Messrs. Mavor & Coulson Ltd.
1-30 p.m.—Coaches leave to join other parties at the Clyde Valley Hydro-Electric Power Station, Falls of Clyde.

(d) 9-30 a.m.—Coaches leave Grand Hotel, Glasgow, for Drysdale and Co., Ltd., Yoker Works.
12-0 noon.—Coaches leave for Grand Hotel, Glasgow. (Visitors make their own arrangements for lunch.)
1-30 p.m.—Coaches leave Grand Hotel, Glasgow, to join other parties at Clyde Valley Hydro-Electric Power Station, Falls of Clyde.
(a, b, c, and d)—All parties join in inspection of the Clyde Valley Hydro-Electric Power Station at the Falls of Clyde and afterwards will be entertained to tea by the Clyde Valley Electrical Power Co.
5-30 p.m.—All the coaches leave for Grand Hotel, Glasgow.
Visitors make their own arrangements for the evening.

Wednesday, 22nd June.

9-43 a.m.—Special Train leaves Central Station, Glasgow, for Edinburgh.
10-50 a.m.—Arrive Princess Street Station, Edinburgh.

ALTERNATIVE VISITS.

(a) 11-0 a.m.—Coaches leave for New Hydraulic Power Station, Imperial Dock, Leith Docks.

(b) 11-0 a.m.—Coaches leave for Portobello Power Station, Portobello.

(c) 11-5 a.m.—Coaches leave for Forth Bridge.
Note.—All coaches return in time for lunch.
1-30 p.m.—Lunch at Mitchell & Co.'s Albyn Rooms, 77 Queen Street, Edinburgh, as guests of the West of Scotland Branch, when visitors will have the opportunity of meeting members of the Lothians Branch.
3-0 p.m.—Coaches start for drive round Edinburgh, including visits to Castle, Palace of Holyrood, Scottish National War Memorial, etc., arriving back in St. Andrew Square at 5-30 p.m. after which visitors will be free until train time as hereunder.
6-55 p.m.—Special Train leaves Princess Street Station, for Glasgow.
8-8 p.m.—Arrive Central Station, Glasgow.

Thursday, 23rd June.

9-20 a.m.—Train leaves Queen Street Station, Glasgow.
10-1 a.m.—Train arrives Craigendoran: thence by boat to Dunoon, Holy Loch, Loch Goil, Loch Long.
1-5 p.m.—Arrive Arrochar, and leave by coaches for Tarbet, Loch Lomond.
1-30 p.m.—Lunch: Tarbet Hotel, Loch Lomond.
4-17 p.m.—Train leaves Arrochar-Tarbet Station per West Highland Railway for Glasgow.
5-41 p.m.—Arrive Queen Street Station, Glasgow.
7-45 p.m.—Civic Reception by the Corporation of Glasgow at the City Chambers.

Friday, 24th June.

9-30 a.m.—General Council Meeting, Grand Hotel, Glasgow.
2-15 p.m.—Assemble at Grand Hotel for Official Photograph.
2-45 p.m.—Annual General Meeting, Grand Hotel.
6-30 p.m.—Annual Dinner and Dance, with Light Buffet, Grand Hotel, Glasgow. (Evening Dress Optional.)

Ladies and Non-Council Members.

9-30 a.m.—Coaches leave Grand Hotel, Glasgow, for drive to Aberfoyle.
2-30 p.m.—Coaches leave Grand Hotel, Glasgow, for
(a) Lang's Bread Factory.
(b) McClure & McIntosh Knitted Wear Factory.

Saturday, 25th June.

Convention Ends.

Should any Member desire to pay a special visit or stay over the weekend, he should give the Hon. Secretary early intimation, when the Committee will endeavour to make the necessary arrangements.

NOTES.

Requests for Hotel Accommodation to be reserved by the Secretary should be made on the Form of Application, but it should be noted that charges for Hotel Accommodation should not be remitted to the Branch Secretary but paid in the usual manner.

Transport to Works, etc., during Convention.

It is specially requested that Members participating in the visits on Tuesday and Wednesday, will not use their own cars, but go by the motor coaches provided. No allowance can be made for anyone not using motor coaches.

Information as to the parking of cars, during the Convention can be obtained from the Hon. Secretary or any of the local committee.

Badges.

Members and friends taking part in the meetings are requested to wear the Badges which will be issued with the Books of Vouchers, etc. Each member of the Local Reception and other Committees will wear a distinctive badge and will be ready to give visiting members any information which may be required. All badges are numbered and a printed list will be issued to every member receiving a badge.

Proceedings of the Association of Mining Electrical Engineers.

MIDLAND BRANCH.

The Use of Oils in the Electrical Industries.

E. R. STYLES, M.Sc., Ph.D.

(*Continued from page* 370.)

TESTING.

Such primary physical characteristics as specific gravity, flash point, viscosity, cold test and volatility are determined by the usual methods which may be found described and illustrated in "Standard Methods of Testing Petroleum and its Products", published by the Institute of Petroleum Technologists. Oils for electrical purposes require certain special properties which are not necessarily possessed by ordinary lubricating oils. Further tests are therefore made to ensure that the oils have the desired chemical and electrical characteristics.

Dielectric Strength.

The dielectric strength of an insulating medium seems to be the most obvious characteristic to test, yet with mineral oils the results of such a test are probably the least satisfactory from the point of view of assessing the value of any given sample of oil. The figures obtained for the Breakdown Voltage are controlled by such a large number of different factors apart from the oil that it is doubtful whether the strength of the oil itself has ever been measured. The real dielectric strength of the oil is obscured by the effect of minute traces of moisture, solid particles, and air bubbles. The question is still further complicated by the fact that high electric stress may cause the formation of an appreciable amount of solid and gaseous deterioration products which influence the breakdown voltage.

By standardising a number of the many variable factors, the B.E.S.A. has been able to give the determination of dielectric strength some significance as a routine test, although it was only possible to fix a minimum value of 30,000 volts for the new clean oil. The results of breakdown tests are only comparable when carried out under identical sets of conditions which must include similarity in type of test cell, form of the electrodes, frequency, wave form and time of application of the voltage, and temperature. In spite of the most careful regulation of as many factors as possible, the test for dielectric strength can only give a rather vague indication as to the amount of moisture or solid matter suspended in the oil. Practically all oils both good and bad, can be made to pass this test if carefully dried and freed from foreign matter. The value of an oil could be estimated more satisfactorily by means of its d.c. resistance, and there is some indication that this is being applied in practice to transformer oils on the Continent in preference to a determination of dielectric strength.

Sludging.

The early pioneer work of Dr. A. C. Michie resulted in the development of the present standard British method of testing the sludging tendency of mineral oils. His attention was drawn to the formation of objectionable deposits in transformers during use. Many different theories had been suggested to account for the phenomenon, but careful experiments shewed that the chief cause of the trouble was oxidation of the mineral oil.

The deposition of sludge in a transformer may not occur for several months so that for the purposes of a laboratory test the process of oxidation had to be accelerated by blowing air through oil at a temperature above normal transformer conditions and in the presence of copper which acted as a catalyst. The Michie Test which is universally applied to transformer oils in this country requires 100 ccs. of oil to be blown with clean air at the rate of 2 litres per hour in the presence of a piece of bright copper having a surface area of 4½ square inches, whilst maintained at 150 degs. C. for a period of 45 hours. The amount of sludge thrown down after dilution with petroleum spirit is estimated gravimetrically. Transformer oils in England are graded according to their Michie Sludge Values: Grade A, 0.1% max.; Grade B, 0.8% max.

Investigators are not however agreed on the methods of testing the tendency of transformer oils to deteriorate in service. Hence we find that almost every country has its own method of testing and it may be fairly stated that no single method is entirely satisfactory. The complexity of the mineral oil itself, the variations in types of transformers and conditions of operation, all combine to render extremely difficult the task of formulating an adequate and practicable laboratory test. Some continental methods incorporate a determination of the amount of acidity developed and its effect upon cotton such as would be used in transformer windings, whilst others include electric stress in an attempt to imitate actual transformer conditions more closely. The essential features of a number of different sludging tests are set out in Table II. (overleaf).

One of the most interesting and comprehensive methods of test is that standardised by the Asea Electric Company of Sweden, based upon the researches of B. Anderson. This investigator has attempted to reproduce all the destructive influences which exist in a transformer during service. Thus a combined copper and iron catalyst is used and the superficial areas of the two metals are arranged to have a ratio of four to one which is the approximate proportion of copper and iron surfaces in an average power transformer. An alternating potential of 10,000 volts R.M.S. at 50 cycles is maintained between two cylindrical metal electrodes immersed in the oil, and these serve at the same time to provide the necessary catalytic surfaces. The tension is equivalent to 10 k.v. per cm. in the oil, corresponding to the stress normally existing in a high tension transformer. Oxygen is passed through a central silver-plated metal tube at the rate of one litre per hour into the oil contained in a glass vessel which is closed by a porcelain lid supporting the electrodes. The test is conducted at a temperature of 100 degs. C. for a period of 100 hours.

A comparison has been made between the results of this method and deterioration actually experienced in transformers. Three 10 k.v.a. power transformers were

TABLE II.

COMPARISON OF METHODS OF TESTING TRANSFORMER OILS.

Test	*Temp. deg. C.*	*Time Hrs.*	*Method of Oxidising*	*Catalyst*	*Elect. Stress*	*Method of Evaluating the oil*
Michie (British)	150	45	Air at 2 ltrs./hrs.	Copper	Nil	Sludge only
Anderson-Asea (Swedish)	100	100	Oxygen 1 ltre/hrs.	Copper and Iron	10 k.v. per cm.	Sludge and acidity of oil
Belgian	170	5	Surface exposed to air in closed oven	Nil	Nil	Sludge and time for initial deposition
Brown-Boveri (Swiss)	112	300	Surface exposed to air.	Copper	Nil	Sludge & cotton test
Italian	110	300	Surface exposed to air in closed oven	Copper	Nil	Sludge, acidity and cotton test
Sligh (American)	200	2.5	Oxygen at 1 atm. in closed vessel	Nil	Nil	Sludge only
Snyder (American)	120	—	Surface exposed to draught of air	Nil	Nil	Time for initial deposition of sludge
French	150	125	Surface exposed to air in closed vessel	Nil	Nil	Sludge only
Kissling (German)	120	70	Oxygen 2 bubbles/sec.	Nil	Nil	Sludge only
Weiss (French)	115	—	Surface exposed to free air	Copper	Nil	Sludge and acidity of oil
Butkov	120	2	Oxygen at 15 atm. in closed vessel	Nil	Nil	Sludge only

used for service tests with different oils and these same oils were examined in the laboratory for sludging tendency by the Anderson-Asea, Brown-Boveri, Michie, and Kissling methods. The results shewed that the Anderson-Asea method was the only one to place the oils in the same order of merit as found in practice. It should however, be mentioned that transformer conditions quite different from those which existed in the particular transformers used for these comparative tests, might render the results of that laboratory test less convincing.

Table II. illustrates the diversity of opinion which exists among transformer oil suppliers and users as to what constitutes a satisfactory form of test. The British Grade A. Specification calls for a very highly refined water-white oil which fails to pass several Continental Specifications for a similar grade owing to the development of acidity and its effect upon cotton. On the other hand some less-refined oils which would be classed as B. Grade by the British Test easily meet these foreign specifications. This curious anomaly has received considerable attention during recent years but general agreement has not yet been reached.

Direct Current Resistance.

This test is applied more particularly to oils for cable impregnation. Although the mechanism of dielectric adsorption and conduction involved in the measurement of direct current resistance of insulating oils is still obscure, the determination of this property is of considerable value. The effects observed in an oil must be conveyed to the finished cable and play an important part in establishing its electrical characteristics.

The measurement may be made between two electrodes of known dimensions immersed in the oil. It is convenient to eliminate the direct measurement of the electrode dimensions and utilise the capacity between them in calculating the resistance, but a properly guarded electrode system is then necessary.

The apparent d.c. resistance varies with temperature, voltage and the time of application of voltage. The measurement may be made at the same time as power factor and specific inductive capacity in a special type of condenser. For routine laboratory tests a period of three minutes' electrification at 100 volts is employed and the temperature varied according to the range of readings required.

Power Factor.

The determination of power factor/temperature characteristics is now regarded as essential for insulating oils especially those intended for cable impregnation. The majority of commercial measurements are made at 50 cycles 1000 volts R.M.S. although audio frequencies have been adopted in certain cases. A Shering Bridge Circuit is employed for power frequencies in conjunction with a special type of condenser and sensitive vibration galvanometer. The condenser is usually of parallel plate type with the plates placed vertically in a metal vessel which contains the oil under test. The design of the condenser and earthed guard system is such as to eliminate brushing, distortion of the electrostatic field at the edge of the plates, the effects of surface leakance, and change of capacity to earth when oil replaces the the air dielectric in the condenser. All terminals on the test panels are provided with earthed guard plates. These precautions are particularly necessary since the power factors to be measured are often very low. Provision is made for drying the oil in the condenser under high vacuum. Extremely accurate work may require the use of a resistance thermometer placed between the plates near the centre to record the temperature, but a properly standardised mercury-in-glass thermometer of suitable construction will give good results provided that the temperature throughout the condenser is allowed to become stabilised and uniform before making a measurement.

The power factor of a good cable oil is very low so that in order to obtain an adequate degree of sensitivity the capacity of the test condenser must necessarily be comparatively large. On the other hand the permissible electric stress in the oil limits the extent to which the clearance between the plates may be reduced. Hence, properly designed condensers are at present rather bulky and require an inconveniently large volume of oil to fill them. Some means of increasing the sensitivity of the bridge to allow for a considerable reduction in the size of the condenser would be very welcome.

Specific Inductive Capacity.

The specific inductive capacity of an oil may be readily obtained at the same time as power factor measurements are being made with the Shering Bridge. As an electrical characteristic it occupies a secondary position somewhat analogous to that of density among physical properties. The dielectric constants of various petroleum fractions vary within very narrow limits. They rise with increase in viscosity and fall slightly on refining.

Deterioration on Ageing.

Transformer oils undergo comparatively large changes during service, and the rate of deterioration may be observed by means of sludge and acidity tests. When however, the amount of deterioration is very much smaller so that no sludge is formed and the acidity is but slightly affected, chemical tests are not sufficiently sensitive to enable the process to be followed accurately. A relatively small deterioration in oils used for high tension cables or high frequency condensers for wireless transmission may render these oils unfit for further use. The progress of ageing in such oils may be most satisfactorily traced by means of power factor measurements.

The laboratory test must not be so drastic as the sludge tests applied to transformer and switch oils. The method of ageing devised by Scott and Riley is probably the best that is at present available for dealing with quantities of oil large enough for use in existing power factor test apparatus. A two-gallon iron can containing 1½ gallons of the oil under test is heated to 110 deg. C. in an oil bath. The screw cap is applied to close the can when 110 deg. C. is attained, and the temperature is then maintained for any desired time. A period of 40 hours has been adopted as suitable for obtaining a fairly reliable estimate of the resistance to ageing. Much longer ageing is sometimes necessary when dealing with very highly refined oils.

APPLICATIONS.

All mineral oils for electrical purposes have certain requirements in common. No appreciable amount of moisture or dirt should be present. Very small quantities of these materials spoil the electrical properties. Inorganic acid should be absent, as this is only found when the refinement has not been carried out correctly and some traces of acid used in the refining process have been allowed to remain in the oil. A trace of organic acidity is permissible but should not exceed 0.2 mgs. KOH per gram. It is due to naphthenic acids which occur in the original crude oil and may persist throughout the refining. The same compounds are revealed by the saponification value for which a limit of 4 mgs. KOH per gram. is prescribed by B.E.S.A. Specification No. 148-1927. Sulphur compounds which are likely to cause discoloration of copper must be avoided, but a small content of sulphur in a chemically inert form is of no account.

Transformer Oils.

In a transformer the electrical losses appear in the form of heat which must be dispersed as soon as possible to avoid injury to the insulation on the windings. The necessary cooling may be obtained from a natural or forced draught of air on the coils, but in most cases a more satisfactory arrangement is made by immersing the windings in a suitable liquid. In the early days resin oils were used but the rapid formation of gummy deposits soon caused trouble in operation. Nearly all modern transformers are immersed in mineral oil which, whilst not a perfect medium, combines more of the desired properties than any other fluid available at an economical price.

The oil conveys heat away from the windings by conduction and convection. The heat may be dissipated by the transformer casing which is provided with deep corrugations or some form of radiator to increase its effective surface. Very large transformers are arranged for water cooling by pumping cold water through coils immersed in the oil or alternatively forcing the oil through a water-cooled radiator separate from the transformer itself. Whenever water-cooling is adopted, precautions must be taken to avoid contamination of the oil with moisture due to leakage or "sweating."

There is practically no difference in specific heat between various types of transformer oil. The transference of heat through an oil depends principally on its viscosity. The oil in contact with the coils absorbs heat by conduction and tends to rise, thereby causing convection currents. Hot oil rises to the top and circulates to the side of the transformer where it is cooled by contact with the casing. The increased density of the cooler oil causes it to sink to the bottom where the cycle starts over again. The lower the viscosity the more rapid is the transference of heat, and the separation of moisture dirt and sludge. As the viscosity is reduced, other factors such as flash point and volatility become important, and there is a definite limit to which the viscosity of a mineral oil may be lowered with safety. Low viscosity is synonymous with low flash point and high volatility. A high rate of loss by evaporation during service would be objectionable, and the possibility of fire would have to be considered. The B.E.S.A. Specification for all grades of transformer oil gives 145 deg. C. min. flash point and 1.6% maximum loss by evaporation.

When transformers work continuously at full load the sludging tendency of the oil becomes very important. A temperature of 90 deg. C. may be allowed and at this temperature mineral oils in contact with oxygen rapidly deteriorate as shewn by a darkening in colour, development of acidity, production of moisture, and finally the deposition of sludge. The deposits tend to block up ventilating ducts between the coils and form a coating on all parts of the transformer which reduces the rate of heat transference owing to its poor conductive properties. The effects are cumulative and if the oil is not replaced or cleaned the increased temperature of the coils may eventually destroy the insulation.

Some means of defining the sludging tendency of a transformer oil is obviously necessary but, as already indicated, the whole question is very complicated. The following factors are involved: The type of crude from which the oil was prepared; the degree of refinement; the conditions under which the oil has to work.

The best transformer oils are prepared from crudes which have a Naphthenic or Paraffin base. There is little to choose between these types so far as sludging is concerned provided they have been refined properly. The higher the degree of refinement the less is the tendency to form sludge, but the development of acidity during use is greater with the more highly refined oils. The refining process may therefore be carried too far so that the production of acidity becomes excessive. There is probably a fairly definite optimum degree of refinement for each type of oil.

In connection with a laboratory sludge test a maximum limit for the amount of sludge produced must be fixed low enough to exclude quite definitely all unsuitable oils. At the same time this may necessitate the exclusion of some satisfactory oils as well. The Michie Test for Grade-A transformer oils errs on the stringent side and as a rule a lower grade oil is accepted by continental users.

The conditions of operation of a transformer play an important part in the selection of the right grade of oil. A transformer operating at a high temperature continuously, demands a better grade of oil than one working intermittently or on part load when the temperature is much lower. Special forms of construction may also influence the choice. Sludging can be materially reduced by eliminating contact between air and the hot oil. The transformer is kept completely filled with oil by means of a conservator tank or expansion chamber fitted above which accommodates the excess oil and allows for expansion or contraction during changes of temperature. These tanks are sealed so that no new air is introduced during normal operation but should excessive pressure or vacuum be developed the situation is met by means of a combined relief and vacuum valve which avoids damage to the tank by bursting or collapse under vacuum. Alternatively, provision may be made for maintaining an inert atmosphere above the surface of the oil. The amount of oxidation which can take place is very much reduced by devices such as these, and usually a grade of oil of higher sludging tendency may be successfully employed.

When transformers are located in exposed positions care must be taken in selecting an oil to make due allowance for the lowest temperature likely to be encountered when the transformer is idle. It is not sufficient to choose an oil with a cold test the same or slightly lower than the minimum temperature experienced. Even the relatively thin oils used in transformers become extremely viscous at low temperatures so that the transference of heat by convection may be seriously retarded long before the setting point of the oil is reached. The danger would be greatest when starting up the transformer after exposure to a low temperature for a considerable period. The windings might become overheated before adequate circulation of oil had been established.

In this connection the A.30 Grade of oil gives a much better factor of safety than other grades of higher cold test.

Mineral oil has a much higher dielectric strength than air and therefore helps to increase the resistance to breakdown of the insulation. In the event of a puncture in the solid insulation the oil immediately flows in and closes the gap. The full benefit of the high insulating properties of the oil can only be obtained when the precautions are taken to prevent contamination of the oil. The dielectric strength is very susceptible to minute traces of moisture, fibres, dust, metallic particles, and similar foreign matter. Mineral oil dissolves a small quantity of water probably not more than 0.01% at atmospheric temperature. The value of the dielectric strength is not so much affected by the dissolved moisture as by suspended globules of water and particles of solid material. An oil containing an appreciable amount of dissolved moisture may still have a higher breakdown voltage than another oil which has fibrous matter in suspension.

Bulk quantities of transformer oil may be prepared in the refinery and pass all tests for breakdown voltage much above the guaranteed standard, but the most difficult part of the operation has yet to be accomplished. The transference of the oil from the finishing tank in the refinery to the transformer without loss of dielectric strength is a very difficult process.

Deliveries of transformer oil are made in bulk by rail or road-tanker or in small quantities in 40/50 gallon drums. In every case it is essential that the containers should be quite dry and free from foreign matter. The oil is usually filled whilst slightly warm and the container sealed up immediately using special washers or gaskets to make the joints. Drums not required for immediate use should be stored on their sides with bung downwards in a dry, sheltered place. If a drum is brought from the cold into a warm room time must be allowed for it to reach room temperature before the bung is removed, otherwise the warm air which enters the drum will deposit moisture on contact with the cold surfaces, and seriously reduce the dielectric strength of the oil.

When emptying a rail or road-tanker the air which enters as the oil is pumped out should be made to pass through some suitable form of drying device to ensure that neither the oil nor the tank itself is contaminated with moisture.

Samples of oil should be taken from the bottom of the container as moisture and dirt tend to settle, so that the worst oil is found at the bottom. Extreme care is necessary in sampling a consignment of oil. The samples, sample bottles and corks, should be specially cleaned and dried before use, and due precautions observed to prevent the deposition of moisture during sampling. Traces of fibre from the washers or beads of water which may have collected near the bung must not be allowed to contaminate the sample.

The care taken in the preparation and transport of oil is of no use unless the transformer itself is properly cleaned and dried before the oil is put in. During subsequent operation the transformer should be protected from the egress of moisture or dust. It is always an advantage to fit some form of breather to dry any air which is drawn in during cooling. Calcium Chloride, Silica Gel, and similar absorbent materials have been employed in breathers, but an oil seal should be fitted to prevent the continuous absorption of moisture from the atmosphere which would rapidly saturate the drying agent.

When transformer oils have become contaminated with dirt and moisture, or undergone appreciable oxidation during service with the resultant production of sludge and water, a cleaning process must be applied. Mechanical impurities can easily be removed and the oil restored to its original condition, but the products of oxidation cannot be completely eliminated with the simple apparatus normally available at a power station. Small portable filter-press outfits are sometimes used, but although these will retain all mechanical impurities the drying action depends entirely upon the capacity of the filter paper for absorbing moisture. The paper must be changed as soon as it is saturated with water or clogged by sludge. The capacity of these filter-presses is very limited.

Centrifugal separators are almost universally employed for dealing with transformer oil. They are much more convenient and will operate continuously except for occasional removal of the bowl to empty out the accumulation of sludge and dirt. The oil is heated before passing to the centrifuge so that the reduced viscosity enables the separation to be more readily accomplished. It should be noted however, that the soluble products of oxidation and dissolved water cannot be removed by centrifugal action. The water may be driven off by heating and blowing with air, but soluble asphaltic substances and organic acids require chemical treatmeant for their removal. This can only be done satisfactorily on the large scale by the oil manufacturer, but the cost of the process is usually prohibitive.

Oils for Switchgear.

Most of the observations made in connection with transformer oils are equally applicable to mineral oils used in the oil tanks of switches and circuit breakers. These oils have to withstand not only high electric stress and heating in contact with air but also the destructive action of an electric arc formed beneath the surface.

Switch oils must provide high dielectric strength, quench the arc and carry away the heat generated as quickly as possible, and allow the gases liberated by destruction of part of the oil to rise rapidly to the surface and the carbon to settle out at the bottom of the tank. All these requirements indicate that the oil should have a low viscosity, but as with transformer oils, here, too, a compromise is necessary between viscosity, flash point, and volatility. There is so much similarity between transformer and switch oils that they are usually classified together. In dealing with switches the difference in performance between A-Grade and B-Grade oils is small, and on grounds of economy the lower grade is frequently employed. The electric arc is so destructive that the differences between oils in respect of their resistivity to its influence, are completely obliterated. At the same time, when the temperature of the oil is likely to be high for a considerable length of time, the more highly refined oils may be advantageous.

The quality of the oil is only one of a large number of factors which govern the performance of switchgear. The mechanical construction must provide for an adequate quantity of oil, sufficient strength to resist the instantaneous pressure developed by arcing, rapid movement of the contacts to reduce the duration of the arc and hence the amount of gas formed, and efficient ventilation of the oil tank. An explosive mixture is produced when the gaseous products from the destruction of the oil, mingle with the air at the top of the tank, and ventilation is therefore particularly important. There are so many factors involved in the design of oil tanks and contacts that practical experience plays a much greater part than theoretical considerations.

Recently there has been an increase in the demand for the "filled" type of metalclad switchgear, and some of the heavier petroleum products have proved very useful for filling current transformer chambers, busbar chambers, and cable boxes. The relatively thin switch oils are liable to find their way through joints quite quickly and loss by creeping or spilling may occur. On the other hand solid bituminous compounds require considerable care in their application to avoid cavitation as the hot fluid compound cools, contracts, and sets. Occasionally, when an alteration of load is made, current transformers have to be changed and then a solid or highly viscous sticky filling compound is a great disadvantage.

Heavy mineral oil of low cold test avoids the disadvantages associated with the use of transformer oil and solid compounds. The possibility of leakage is considerably reduced and the oil may be filled easily without heating, or chance of trouble due to occluded air and cavitation. The oil will readily flow away through a drain plug leaving the apparatus coated with a thin film of clean oil. This facilitates inspection and replacement of instrument transformers. It is necessary however, when using heavy mineral oil instead of solid compound, to take steps to prevent contamination with dirt or moisture and to provide oil-tight joints.

Cable dividing boxes, joint boxes, and sealing ends should preferably be filled with an oil similar to that used for impregnating the cables so that the electrical characteristics of the cable are unaffected by oil drawn in during cycles of heating and cooling. A solid compound prevents this breathing action, and may cause the formation of voids in the oil near the ends of the cable, which is accentuated by the fact that traces of gas are unavoidably absorbed from the atmosphere during installation. When dealing with low tension cables solid bituminous materials may be satisfactory. They give an excellent seal with metal and present considerable mechanical resistance to moisture and dirt which enables a cheap type of joint box to be used. But the electrical characteristics of bitumens are relatively poor; and further, in high tension cables the tendency to form voids must be reduced in every possible way. Mineral oils can provide the necessary high electrical properties and fluidity to allow for expansion and contraction in the cable. The better electrical characteristics and ease of filling of mineral oil should enable a smaller joint box to be utilised to make up for the increased cost of carefully machined faces and good gaskets required to prevent contamination.

High tension terminals are sometimes partly insulated by means of mineral oil. There is a limit to the thickness of porcelain which can be successfully fired, and when very large terminals are required they are made hollow and the space filled with a suitable dielectric. For this purpose also a heavy mineral oil presents definite advantages in respect of minimising leakage, ease of filling, and high dielectric properties.

As a rule the choice of filling materials for the various parts of metalclad switchgear, transformer and cable accessories, is governed by limitations of design such as available space, prevention of leakage or contamination, and facilities for filling. It is suggested, however, that a wider use of fairly high viscosity, low cold test, mineral oils in suitably designed current transformer and busbar chambers, cable ends and joints, and terminals, would eventually prove advantageous.

Cable Oils.

Cable manufacturers are not agreed as to what constitutes the best medium for impregnating high tension cables. Table III. indicates some of the variations existing in current practice. Obviously the task which confronts the oil-supplier is very difficult as at present there is no prospect of agreement in respect of the type of oil required. Further, the majority of cable makers choose to mix a large percentage of rosin with the

TABLE III.

PROPERTIES OF THE MINERAL OIL CONSTITUENT OF VARIOUS H.T. COMPOUNDS.

Specific Gravity.	Closed Flash Pt. deg. F.	Viscosity Secs. Redwood 140 deg. F.	Cold Test deg. F.	Type of Oil.	Additions of Rosin.
0.941	440	500	10	Texan. Hy. distillate	Nil
0.909	400	493	10	Blend of cylinder stock and light distillate	Nil
0.915	510	745	10	Western cylinder stock	30%
0.895	515	550	40	Penna cylinder stock	18%
0.949	500	1024	20	Texan heavy distillate	25%
0.914	508	662	70	Western cylinder stock	50%

mineral oil and the properties of the resulting compound are very different from those of the straight mineral oil. Apart from the question of the desirability or otherwise of the use of rosin, there are certain characteristics required in the mineral oil itself.

The oil should be free from organic or inorganic acids, and sulphur compounds likely to attack the paper or metals with which it comes in contact in the cable or during manufacture. The viscosity must be low enough to allow thorough impregnation of the paper within a reasonable time but high enough to resist any appreciable amount of drainage when the cable is laid on a slope, or radial movement of the oil under electric stress.

In practice the viscosity of the oil is often completely disguised by the addition of rosin. A survey of the materials at present in use for the impregnation of high tension cables shews a variation in viscosity at 200 deg. F. from 120 to 2000 seconds Redwood No. 1. The less viscous oils and compounds enable low power factors to be obtained more readily but the tendency for drainage to take place with consequent formation of voids is greater. A cable impregnated with very viscous compound requires great care in handling during installation.

It is generally recognised that the oil should not have a setting point within the working range of cable temperatures. If the cable is cooled below the setting point there will be a risk of void formation, as contraction of the impregnating medium occurs. The removal of all wax from cable oils is therefore of considerable importance. Some oils are naturally wax-free, but most cylinder stocks have to be specially treated.

Specific heat, thermal resistivity, volumetric coefficient of expansion, gas absorption, and specific inductive capacity vary within very narrow limits according to the type of oil, and are practically independent of any treatment given by the oil-refiner. The choice of type of oil is usually governed by other factors such as viscosity/temperature gradient, setting point, resistance to oxidation, and not by the former characteristics. The rate of expansion is probably the most important but this happens to be lowest for high gravity oils which tend to deteriorate more rapidly than those of low gravity.

The dielectric strength of an oil for cable impregnation is of minor importance. A high breakdown voltage only serves to shew that the oil is reasonably free from dirt and moisture. The cable manufacturer carefully degasifies the oil or compound before use and the final traces of moisture are removed long before a sufficiently high degree of degasification has been attained.

In order that dielectric losses in the cable during service may be kept down as much as possible, the oil must have high direct current resistance and low power factor. The d.c. resistance always decreases rapidly with increase of temperature but when power factor measurements are plotted against corresponding temperature a curve incorporating a minimum point is frequently obtained. It is obviously an advantage to use an oil or compound which, in conjunction with the cable paper, gives a minimum point to coincide with the average operating temperature of the cable.

An ageing test for cable oils is very useful. It may be argued that no oxidation occurs once the cable has been completed, but during manufacture there is considerable opportunity for the oil to deteriorate in contact with air at high temperature. The adoption of closed circuit systems with high vacuum for handling cable oil during the process of impregnation has done much to reduce the deterioration, but oxidation cannot be completely eliminated. In the average impregnating system it is still necessary to maintain in circulation fifty or more times as much oil as is required for insulating a single cable. Any method which enables a cable to be put through the impregnating process using only slightly more oil than is actually needed in that cable, presents obvious advantages in respect of deterioration and capital outlay.

No oil should be judged by its initial electrical characteristics only. The rate of increase in power factor and decrease in d.c. resistance during ageing should also be considered. Almost any type of oil can be highly refined to obtain good electrical properties, but only a few special types will retain them long enough to suit the processes of cable manufacture.

The deterioration of mineral oils and cable compounds under electric stress has been the subject of some very interesting investigations during recent years. It has been observed that a waxy solid substance is sometimes produced in high voltage cables during service although breakdown has not necessarily occurred. Experiments made by Hirschfield and his co-workers of the Detroit Edison Company have provided valuable information in this connection, which throws light on some of the probable causes of cable failure.

Mineral oils used for cable impregnation were subjected to the discharge from a cathode-ray tube. This caused the formation of solid and gaseous products by polymerisation and condensation. The solid material was shewn to be similar to the waxy compound found in cables. The gas proved to consist chiefly of hydrogen, but the volume liberated by a given quantity of oil was very much greater than that found to accompany the production of wax in a cable. Further tests shewed that the paper forming part of the cable insulation when subjected to a similar discharge, gave off carbon dioxide. Under the influence of electrical bombardment hydrogen and carbon dioxide will combine to produce water and this would account for the small amount of gas actually found in the cable. The cathode ray discharge is claimed to have the same effect as that of a silent electric discharge such as might occur in a cable void, but the deterioration is produced much more rapidly.

It was concluded that the formation of gases and moisture in the cable during use is one of the most important factors in causing breakdown of cables in service. The design of cables should be modified to prevent the formation of voids and consequent silent electric discharge, or alternatively the insulating materials employed in the cable should be such as would not give moisture and gaseous products when subjected to the discharge.

Experimenting with different types of mineral oil it was found that those containing most unsaturated compounds gave the least volume of gaseous products due to the absorption of part of the hydrogen by these compounds immediately it is formed. A large proportion of unsaturated substances in an oil indicates a low degree of refinement poor electrical characteristics and little resistance to oxidation. Hence no general improvement in the life of a cable could be expected to result from the adoption of such unsaturated oils for cable impregnation. All other factors concerning the oil which influence the quality of a cable, demand the use of a highly refined product containing as small a percentage of unsaturated compounds as possible.

Most investigators are now of the opinion that electric stress alone could not produce the waxy solid.

Electric discharge in a void must take place first, the initial formation of the void being due to some fault in the manufacture of the cable or type of impregnating medium employed. Once the void has formed deterioration proceeds whatever oil or compound is used, although the rate of evolution of gaseous products, and hence the expansion of the void, will vary inversely as the content of unsaturated compounds. It appears therefore, as if the more saturated oils, typified by those of Pennsylvanian origin would give rise to more rapid deterioration once a void were formed, than the less saturated oils represented by the Texan type.

Cable experts are divided into two groups on the question of the use of rosin in impregnating compounds. Some of the points brought forward for and against its use are enumerated below :

For the Use of Rosin.

(1) Rosin enables a higher viscosity compound to be used, than any mineral oil.

(2) Rosin possesses certain sticky properties which are said to offer greater resistance to displacement of the compound by drainage or electric stress. In the event of the formation of voids, they would be kept small and have little tendency to coalesce.

(3) The coefficient of expansion is slightly reduced by the addition of rosin.

(4) An adjustment of the minimum point on the power factor/temperature characteristic can be made by altering the percentage of rosin in the compound.

Against the Use of Rosin.

(1) Rosin raises the setting point of the compound.

(2) Thermal resistivity is slightly increased.

(3) Rosin deposits objectionable sludge on oxidation, and acids are produced which attack metals, paricularly copper.

(4) When rosin compounds are heated under high vacuum for degasification, troublesome acidic liquids may be carried over into the pumps.

Most European manufacturers favour the use of rosin but in America mineral oils are usually employed.

Within limits the requirements in compounds for low tension are similar to those for high tension cables, but the electrical properties and stability towards oxidising influences need not be as good, so that cheaper products of a less-refined character may be utilised. The manufacture of satisfactory low tension cables does not present such difficulties as are encountered with high tension cables.

Many of the troubles associated with H.T. cables have been eliminated in the type of oil-filled cable in which the movement of oil is actually encouraged by the provision of a central oil duct. Oil is fed to the cable at suitable points to ensure that a pressure not less than atmospheric is always applied. The risk of void formation is thereby greatly reduced. A highly refined mineral oil slightly thicker than transformer oil is used in order to facilitate the flow of oil which compensates for the variations in pressure during changes in the temperature of the cable in service.

The author is indebted to Mr. Wm. Lee for his helpful criticism, to Standard Telephones & Cables Ltd., Gambrell Bros., Ltd., English Electric Co., Ltd., Ferguson Pailin Ltd., Drake & Gorham Ltd., and Pirelli General Cable Co., Ltd., for the loan of photographs or lantern slides, and to Silvertown Lubricants Ltd., for permission to present this paper.

SOUTH WALES BRANCH.

Concert and Supper.

A very successful smoking concert and supper was held by the South Wales Branch at the Grand Hotel, Cardiff on Saturday, January 23rd last, some 80 members and friends attending. Major W. Roberts, the Branch President, occupied the chair and was supported by the Branch officials.

The principal guest of the evening was Capt. J. McLeod Carey, H.M. Divisional Inspector of Mines, who, in responding to the toast of the Branch, said the Association might reasonably take some credit to themselves from the fact that not a single accident owing to electrical failures had taken place in the district during the whole of last year. This reflected great credit on the electrical engineers, the majority of whom were members of the Association.

The Chairman referred to the absence of the President of the Association—Major E. Ivor David—owing to illness, and expressed the hope that he would have a speedy recovery.

The success of the evening was largely contributed to by Messrs. G. Avery, Ll. L. Fullerton and J. T. Bourne who gave musical and elocutionary items.

The function was arranged at the expressed wish of a large number of colliery members who were unable to attend the official dinner and dance which proved a big success in December and it was very gratifying that this special social meeting was also highly successful, especially in view of the fact that it was an innovation for the South Wales Branch.

YORKSHIRE BRANCH.

A.C. Rectification with Special Reference to Mercury Arc Rectifiers.

CECIL C. HIGGENS.

(*Paper read 9th January,* 1932).

In view of the attention given of late to A.C. Transmission and Distribution and to the tendency—officially encouraged and speeded up by the Central Electricity Board—to change over existing d.c. networks to the L.T.A.C. system, one is inclined to forget that there is still a demand for d.c. plant. Actually, that demand is likely to be a growing one. The growth of wireless telephony has accounted for a universal demand for battery charging facilities or, alternatively, for small units capable of giving a direct current supply to the owners' sets.

The a.c. induction motor is admittedly remarkably simple and reliable but, in certain industries, particularly in engineering, the superior starting characteristics and simple speed control of the d.c. motor frequently justifies the retention of, or in the case of new works, the adoption of, the d.c. system.

In many chemical processes d.c. is a necessity.

For traction purposes, although much work has been done and money spent by the protagonists of A.C. Railway Electrification, it is now generally admitted that for light, suburban, interurban and main line railway electrification the direct current motor stands alone.

Finally, and now we are looking into the future, although it is present day practice when transmitting power over an appreciable distance to adopt high tension a.c. transmission, developments have recently been taking place which suggest that before long high tension d.c. may be a serious rival to the present a.c. system.

Up to comparatively recent times, the supply of direct current inevitably called for what is known as dynamic plant. For converting a high tension a.c. supply into a low tension d.c. one—the subject with which this paper primarily deals—motor generators, rotary converters or motor converters were necessary. The basic principle of these machines being commutation: compared with these moving machines, a static transformer seemed delightfully simple.

Physicists and electrical engineers, however, were not content to let the matter rest. At the close of the last century a new principle had been discovered whereby conversion from a.c. to d.c. was possible. The principle we will term valve rectification. By this means the static a.c. to d.c. substation became a possibility. Much work, of course, had to be done before the principle could be used commercially, and it is only comparatively recently that static units up to some 16,000 amps. capacity and, for high voltage work, up to 30,000 volts became a commercial proposition.

The author is not venturing to offer a highly technical or mathematical paper. Nevertheless, since the principles underlying the design and operation of dynamic plant are familiar to all, and whereas to many the principles of valve rectification are still more or less shrouded in mystery, a brief account of the physics involved is desirable.

Until comparatively recently, matter was considered to be made up of a number of exceedingly small particles; probably minute, hard spheres. The ultimate or smallest particle of an element such as hydrogen or iron was called an Atom and the corresponding particle of a compound such as water or sodium chloride a Molecule. For purposes of chemical science the atom and molecule were perfectly satisfactory units; it was not necessary to regard either as having any structure.

During the early part of the 19th century chemists were busy with the Atomic Theory. Atoms were weighed and their weight tabulated, commencing with Hydrogen the lightest, and ending with Uranium the heaviest of the known elements. Then a peculiar thing was noticed. Mendeleef discovered the Periodic Table of Elements. He shewed that if the elements were arranged in the order of their atomic weights certain properties appeared periodically through the table. This similarity of properties in different elements suggested the possibility of the atom possessing a structure—the structure of each element being distinct and individual but the atomic structures of a series of elements of like properties having something in common.

For a quarter of a century the atom lay under suspicion of not being all that it had been assumed to be, or rather of being very much more than its early sponsors had thought.

Between 1895 and 1900 a series of vitally important experiments were made on the flow of electric current between electrodes contained in a vacuum tube. It was noticed that when a sufficient potential was applied between two electrodes in vacuo a stream of something passed from the negative to the positive plate. That this something moved in straight lines was shewn by the fact that a shadow would be cast on the positive plate if a solid object were interposed between the plates. What was perhaps more important was the fact that this stream of something had the extraordinary property of passing through thin sheets of metal. It was realised that the units making up this stream must consist of some kind of particle which was very much smaller than the atom. This new particle was called an electron. Research soon shewed that the electron was indeed much smaller than the atom—it was about 1/2000th of a hydrogen atom. Further, whenever and however electrons were obtained they were always identical.

It was realised that the electron was closely connected with matter and a theory was propounded that every material atom was composed of electrons.

Normally an atom of matter is electrically neutral, whereas an electron was found to be essentially a negative electric charge. Some modification to the all-electron theory was then found to be necessary and by degrees the present generaly accepted theory was arrived at. Modern physicists regard a particle of matter as consisting of a central nucleus made up of positive and negative electric charges. The positive units are always in excess of the negative units or electrons and the nucleus is said to possess a positive nuclear charge. Revolving round this nucleus are one or more further electrons termed orbital electrons, the number being just sufficient to balance the positive nuclear charge.

Having arrived at the electron, a vital unit for the proper understanding of Rectification Problems, it will be as well to leave the physicists to carry on with their work: otherwise, there might be the danger of finding this paper and rectifiers mere curves in space-time!

It is as well here to point out that the author makes no claim of finality in respect of any theories referred to. A theory is merely a way of explaining phenomena. A survey of the past teaches as that human theories, though satisfactory in their day, have constantly required modification as fresh phenomena have been observed. It would be presumptious to claim that present-day ideas, unlike those of past generations, are anything more than convenient stepping stones. This by way of parenthesis.

Another matter about which we require to be reasonably clear is the nature of the flow of an electric current. We are all familiar with the flow of current through a metallic conductor but few of us could explain exactly what is happening. The metal of which the conductor consists is made up of a number of atoms or particles such as have already been described. An interchange of orbital electrons is continually taking place and there are also a number of free electrons, although each individual electron is only free for a short space of time. An electric potential applied to that metal causes the free electrons to move towards the positive pole and it is this circulation of electrons round the circuit which constitutes an electric current.

A metallic conductor is not however necessary for the movement of electric charges. Under certain conditions a flow of current can take place through empty or partly gas-filled space.

It has been stated that a flow of electrons constitutes a current and further that there are a number of free electrons present in a metallic conductor. These free electrons are in a state of agitation, their velocity depending upon the temperature of the metal. If sufficiently agitated some of these free electrons are capable of passing through the surface of the metal and, under certain conditions, of passing through space under the influence of an electric field. This phenomenon is referred to as Thermionic Emission. The readiness with which this electron emission takes place varies with different metals owing to the readiness or otherwise with which the electron may be separated from their respective atoms.

Suppose now that we have an enclosed vessel containing two electrodes, one of which may be heated electrically or otherwise; and, further, that the vessel is completely exhausted of all gas or vapour. Let the heated electrode consist of a tungsten filament. If this filament is heated and a sufficiently negative potential be applied to it with respect to the other electrode, thermionic emission will take place. A flow of electrons occurs from the negative filament to the positive electrode—from cathode to anode. If now the applied potential be reversed, the filament or cathode becoming positive with respect to the anode, electrons are not drawn out of the cathode and the flow of current ceases. The apparatus is therefore acting as a non-return valve and obviously could be adapted for rectification purposes.

Only a very small current would be able to flow with the apparatus described. If the filament were coated with thorium or barium oxide a very great increase in the electron emission and consequent flow of current would be noted, but even then the potential necessary to cause this flow would be considerable, the reason being that the electrons immediately they leave the cathode form a negative space charge which tends to counteract the effect of the electric field due to the positive potential applied to the anode, thus slowing down the rate of further emission.

If now a small amount of gas be admitted to the vessel an entirely new phenomenon takes place. The electrons in travelling from cathode to anode collide with the gas particles causing some of the orbital electrons in these gas particles to become detached leaving in each case a positively charged particle or positive ion. The gas is said to be ionised. The positive ions are attracted to the cathode and during their flight counteract the negative space charge effect already mentioned. Under these conditions a great increase in the rate of electron emission would be observed.

If arrangements are made for controlling the gas pressure in the vessel it will be found that there is an optimum value. An increase above that figure results in a decrease in the electron emission owing to the too dense barrier of gas molecules opposing the electron stream. On the other hand, if there is insufficient gas present a sufficient number of positive ions to counteract the negative space charge cannot be formed and again the rate of emission falls.

This is the principle upon which the modern rectifying valve is constructed. It remains to examine the method of connection in order to utilise the valve for rectifying an a.c. supply.

Assume the anode of a valve, such as has been described, be connected to one pole of a single-phase a.c. supply, the cathode connected to some form of load, such as an accumulator, and the other terminal of the accumulator, to the other pole of the a.c. supply. When the filament is heated current will pass only when the plate or anode is at a positive potential in respect of the filament or cathode—that is during one half or part of one half cycle, the period during which current will flow depending upon the value of any back e.m.f. in the circuit. This is referred to as half wave rectification.

If now a single-phase transformer with a centre tapping on the secondary be added to the equipment we can go a step farther. If two valves are employed each with its anode connected to one transformer secondary terminal, the filament or cathodes joined together and a load connected between the common cathode connection and the centre tapping, full wave rectification will be obtained. One valve passing current during one half cycle and the other valve during the other half cycle.

An obvious simplification of this arrangement is to incorporate the two anodes in one container and to use a common cathode.

By using three anodes in one valve and a three-phase transformer with a star connected secondary, a further step forward is made towards obtaining not only a unidirectional but actually a continuous current.

Such valves are made for ordinary commercial purposes up to one or two k.w. capacity; they are also made for high voltage work and many are in service supplying d.c. motors for lifts, etc. for battery charging cable testing and, in fact, for any purpose where a small d.c. supply is required. They have the advantage of being static, requiring no attention, but the disadvantage of, in time, requiring renewal owing to the disintegration and final failure of the filament.

A voltage curve obtained from a three anode valve is not a straight line but should such a characteristic be desirable the introduction of reactance into the rectifier circuit has a marked smoothing effect and gives a voltage curve sufficiently near to a straight line for most purposes. For ordinary power work no smoothing other than that due to the transformer and load reactances is necessary.

While very convenient for small outputs, the Thermionic Valve such as has been described has limitations. The cathode material, in the form of a heated filament, is subject to deterioration and this type of cathode would appear to be limited as regards the rate of electron emission and therefore output capacity. Simultaneously with the development of this type of current valve or rectifier, a somewhat different type with far fewer limitations was being developed, namely, the Mercury Arc Rectifier with which is associated the name of Mr. Peter Cooper Hewitt.

The principle of the Mercury Arc Rectifier is similar to but not identical with that of the thermionic valve. Primarily an arc depends upon the presence of a hot electron emitting cathode and anode. In this respect, the Mercury Arc Rectifier is similar to the valve already described. A certain voltage is necessary to maintain the arc. This varies with the cathode material, temperature and gas pressure. Under any given set of conditions a certain voltage will be capable of causing a spark discharge between the electrodes. If now the voltage necessary to maintain the arc once it is formed is less than that required to cause a spark discharge, as long as the anode is sufficiently positive compared with the cathode, an arc will be maintained. If the supply is an alternating one and the potential between anode and cathode falls below the figure necessary for arc maintenance, the arc is extinguished and fails to start when the potential between anode and cathode is reversed. Provided some means is devised for keeping the cathode at a sufficiently high temperature, rectification by this method is clearly possible. Should, however, the electrode materials and vapour conditions be such that on reversal of polarity a spark discharge may take place this would probably be sufficient to cause the arc to start in a reverse direction and rectification would not be possible.

A cathode consisting of mercury contained in an exhausted vessel meets the first set of conditions very satisfactorily. In this element the electrons are loosely held by the positive nuclear charge. Electron emission can therefore readily take place at a comparatively low temperature and voltage. Mercury vapourises readily thus supplying a vapour for ionisation purposes. Further, since at normal temperatures mercury is liquid, the vapour formed at the hot cathode readily condenses, running back into the cathode receptacle without loss.

Towards the end of the last century much work was being done on the rectifying properties of the mercury vapour lamp, and on arc rectification generally, by numerous investigators in America, Germany, Switzerland and France. Mr. Cooper Hewitt achieved considerable success with a glass enclosed Mercury Arc Rectifier which, as a result of steady development, is to-day the best known and most used of the glass bulb type of Mercury Arc Rectifiers.

The modern Glass Bulb Rectifier of the Hewittic type consists of a pear-shaped glass vessel into the neck of which are sealed glass tubes containing a right-angled bend The larger portion of the bulb is uppermost and its function is to provide a cool surface for condensing the mercury vapour. The mercury pool forming the cathode lays at the bottom of the neck of this vessel. The glass tubes above mentioned contain the anodes. For small bulbs from 45 amps. to about 130 amps. output, three anodes are used. From 130 amps. to about 265 amps., six anodes are now used.

From what has been said previously it is obvious that the mere application of a potential between anode and cathode will not cause the apparatus to start functioning. If the normal voltage between anode and cathode were sufficient to cause an arc to jump across, rectification would not be possible because the arc would form as readily in one direction as the other. A hot cathode spot is necessary in order that electrons may be expelled and also that mercury vapour may be available for ionisation.

The starting up therefore calls for additional apparatus, namely, an ignition anode arranged in some way to make actual contact with the mercury cathode, and then to break contact thus striking an arc. Originally ignition was obtained by tilting the bulb so that the mercury cathode flowed up against the ignition anode to make the circuit, the arc being struck when the bulb returned to its normal position. There were drawbacks to this method. The bulbs of glass are necessarily somewhat fragile and if it is possible to avoid tilting them, all the better. Various ingenious methods to avoiding tilting have been evolved, but probably the most generally used method to-day is that which uses a thermally-controlled contact which, when cold, touches the mercury, and when heated by the passage of current is withdrawn therefrom, thus striking an arc.

Should the arc thus struck happen to be in the correct direction—i.e., if current is flowing from ignition anode to cathode, a hot cathode spot will be formed. If the direction of current is in the opposite sense, a cathode spot is not formed on the mercury and the operation has to be repeated until a spot is formed. The whole operation is automatic. The supply to the ignition anode is obtained from a small auxiliary transformer and by a system of relays the ignition apparatus is energised until a flow of current is established through the anodes next to be described.

We have gone so far as to obtain the cathode spot. Although a potential may be applied to the main anodes, should the main d.c. switch be open no current can flow. At the same time, it is necessary to maintain the cathode spot having once obtained it. This is done by providing two excitation anodes supplied by an auxiliary transformer and connected up to a small artificial load. A continuous exciting current is thus obtained irrespective of what is happening on the main anodes. It is this exciting current which is arranged by means of a relay to de-energise the ignition gear.

The main anodes, as has already been mentioned, are sealed in the tubes or arms which connect into the neck of the main vessel. The heads of these anodes are usually made of a carefully prepared, homogeneous graphite.

The transformer connections for a glass bulb rectifier are fairly obvious from what has gone before. It is essential to have a star connected secondary in order that a neutral point may be available since this has to act as the negative pole of the system. The primary winding could be either delta or star connected, but it is usually the former.

For reasons which will be dealt with shortly it is not advisable to connect the transformer secondaries direct to the anodes in the bulb: both fuses, and in the case of a three anode bulb, choke coils, are necessary.

Before proceeding farther we will consider briefly the factors which have to be considered in building a bulb such as has been described. First of all an extheremly high vacuum is essential. This will be in the neighbourhood of 0.001 mm. Hg.—almost a perfect vacuum. There are no means of recovering this vacuum should a leak develop or should the outside air percolate through the glass. Further, not only do the glass-ware and seals have to be such that this high vacuum is maintained at ordinary temperatures, but considerable variations in temperature have also to be taken into consideration. Exceedingly high grade glass-ware and workmanship are, therefore, necessary.

The normal operation of such a rectifier offers no difficulties but there is a danger which always has to be guarded against in mercury arc rectifiers, namely, back fires. Should, through heavy loading or some other cause such as a globule of mercury forming on an anode, a cathode spot develop on one of the main anodes, this spot being capable of emitting electrons, an internal short circuit may develop between anodes. On account of the fragility of the glass bulb, back-fires must be guarded against, hence the location of anodes in separate sleeves or tubes and the necessity for fuses in the anode circuits.

Bulbs are made, as has already been mentioned, with either three or six anodes, In the case of the six anode bulb a double star secondary winding is usually employed. The two secondary windings on each limb are wound in opposition and the neutral point of each star system is brought out.

Unless means are adopted to modify the natural functioning of a rectifier, such as has been described, only the anode at the highest potential would carry current, the current ceasing in an anode immediately the next rising anode commenced to function. This would result in a voltage curve made up of the peaks of a three or six phase wave from intersection to intersection. Since the total load has to be carried by each phase winding in turn for a short period only, the transformer would be large compared with a normal transformer of similar rating. To a large extent this can be overcome in the three anode bulb by adding chokes to the anode circuits. The reactance, both in the transformer and in the chokes prevent the current falling to zero in one anode circuit until an appreciable time after the current has started flowing in the next anode. Part of the time, therefore, two anodes are working in parallel, the e.m.f. curve is to some extent smoothed and the transformer windings are more usefully employed, resulting in a smaller transformer.

With the six anode bulb and double three-phase winding a further refinement is possible. An absorption choke coil or interphase transformer, consisting essentially of a centre-tapped iron core inductance, can be connected between the two neutral points of the main transformer, the centre tapping point acting as the return or negative. This produces an enhanced overlapping effect and a much improved voltage regulation as compared with anode chokes.

The last and largest of the types of rectifier to be described is the steel enclosed power rectifier. Various firms and individuals, starting in about the year 1905, experimented with rectifiers built in a metal, rather than a glass, container. Many difficulties were encountered. However, Messrs. Brown-Boveri persisted in their investigation and succeeded in producing a satisfactory commercial apparatus. They have now manufactured some one and a quarter million k.w. of rectifiers. To-day there are several different types of metal rectifier on the market, but all are necessarily based upon the experience and discoveries of the Brown-Boveri engineers.

The illustration, Fig. 1, shews a section of a modern Brown-Boveri rectifier. It consists primarily of a circular water-cooled tank, at the bottom of which and insulated therefrom is the mercury cathode. The cover to this tank is also water-cooled and through it pass the main and excitation anodes. Rising out of the centre of the lid or, as it is called, the anode plate, is a cylindrical chimney-like structure, also water-cooled, the main function of which is to provide cooling surface for condensing the mercury vapour given off from the hot cathode.

Ignition is obtained by means of the central rod which, when the main switch is closed, is caused to function in the following manner. The rod is normally held clear of the mercury cathode by means of a spring. Upon the closing of the main a.c. switch a solenoid which pulls the rod down into the mercury cathode is energised. Immediately the ignition circuit is thus established and current flows—the supply being from an auxiliary transformer—the solenoid is de-energised, the spring raises the rod, and an arc is formed on the surface of the cathode pool. If, as described in connection with the glass bulb rectifier, the direction of current in the arc is in the correct direction, the necessary hot electron-emitting spot will be formed on the mercury and current will now flow from the excitation anodes through the cathode and artificial load, thus maintaining the cathode in an active condition. A current of about five amperes is required for this purpose. The excitation current passes through a relay which causes the ignition apparatus to be de-energised. Should the arc strike in the wrong direction no excitation current can flow, and the striking of an arc is repeated until such time as a cathode spot on the mercury is established. Fig. 2 illustrates the necessary connections.

The ignition system thus described functions with a.c. Only an auxiliary transformer and some simple, robust relays are required for ignition purposes. Originally it was thought that a d.c. supply would be necessary for establishing the cathode spot, and a small motor generator was used to obtain this supply. The a.c. ignition system has, however, proved perfectly satisfactory and the author can see no good reason for the complicating of a sound and simple system by the addition of a motor generator or small glass bulb rectifier, such as some people are doing.

So much for the ignition and excitation apparatus. There are other points of interest in the construction of this rectifier.

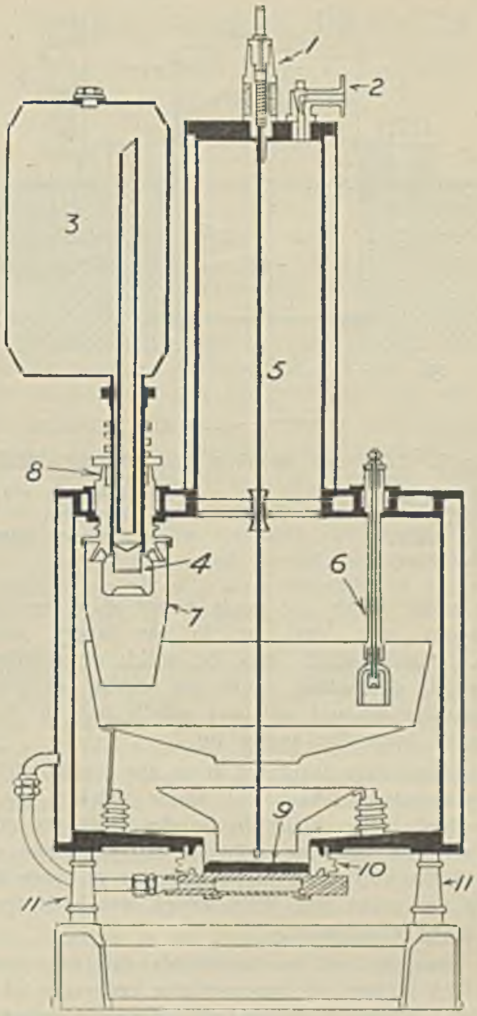

Fig. 1.—Simplified cross section of water-cooled steel rectifier.

1.—*Ignition Gear.*
2.—*Vacuum Cock, connection to vacuum pumps.*
3.—*Anode cooler.*
4.—*Main anode.*
5.—*Ignition rod.*
6.—*Excitation anode.*
7.—*Anode sleeve.*
8.—*Anode bushing.*
9.—*Mercury cathode.*
10.—*Cathode insulator.*
11.—*Insulating feet.*

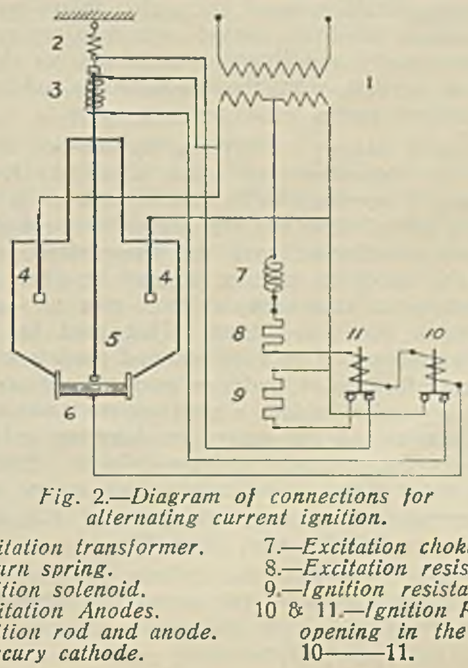

Fig. 2.—Diagram of connections for alternating current ignition.

1.—*Excitation transformer.*
2.—*Return spring.*
3.—*Ignition solenoid.*
4.—*Excitation Anodes.*
5.—*Ignition rod and anode.*
6.—*Mercury cathode.*
7.—*Excitation choke coil.*
8.—*Excitation resistance.*
9.—*Ignition resistance.*
10 & 11.—*Ignition Relays opening in the order* 10——11.

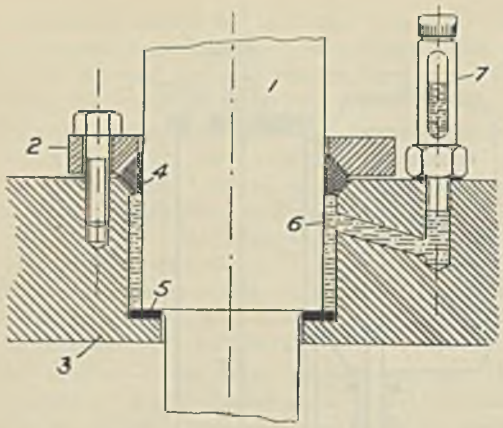

Fig. 3.—Electrode bushing with mercury seal.

1.—*Electrode bushing.*
2.—*Flange.*
3.—*Anode plate.*
4.—*Rubber ring.*
5.—*Asbestos ring.*
6.—*Mercury.*
7.—*Mercury gauge.*

The anode heads are made either of a very special homogeneous pure steel or, in the larger sizes, of graphite. Anode shafts may be solid, or tubular and water-cooled, depending upon the rating of the rectifier and the amount of heat which has to be conveyed away from the anode tip.

The anodes are insulated from the anode plate and are surrounded by sheet-steel anode shields, the function of which is to shield the anodes from the mercury vapour arising from the cathode, also in some degree to control the arc. The shape and size of these shields is highly important and their design has been the subject of much experiment.

The provision of anode shields did not prove to be sufficient in itself to prevent the occurence of backfires. An additional device was evolved, namely, the anode grid or screen. This consists of a metallic grid fixed in the shield fairly close to the anode head. Usually this grid is not insulated from the shield. It can, however, be insulated from the shield and energised by a source of potential. Notable experiments have been carried out on those lines during the past year or so, and by means of grid control it has proved possible to do all sorts of unexpected things with rectifiers, namely, to obtain voltage control, to run reversed, i.e. feeding in d.c. and obtaining a.c., frequency changing, etc. But to deal with those adaptations offers more than sufficient scope for a separate paper.

The next matter of interest is the question of seals: the extreme importance of which is evident from the fact that it is necessary to be able to maintain a vacuum of the order of 0.001 mm. Hg. within the cylinder. A seal must be effective over the temperature range at which it is called to function: it must be proof against deterioration: it must not in itself give off any gas. Many forms have been tried. That used by Brown-Boveri is known as a mercury seal and consists primarily of an asbestos gasket under a head of mercury. The mercury is carried up into a glass indicator which shows at a glance should the gasket be defective and permit of mercury being drawn into the cylinder. Every seal is thus fitted with an indicator which is an immense advantage since there can then never be any difficulty in locating a defective seal. (See Fig. 3.)

We have seen how the cylinder is made vacuum tight. Now we come to the method for obtaining the vacuum. Two pumps in series are employed. First there is the rotary, oil-immersed pump capable of exhausting down to about 0.04 mm. Hg. absolute pressure: this is called the preliminary vacuum pump. A high vacuum, mercury vapour pump is connected directly to the rectifier cylinder and exhausts into the suction side of the rotary pump. This high vacuum pump compresses to about 0.5 mm. Hg.; the characteristics of the two pumps overlapping it is easily possible by this means to produce a vacuum of the order of 0.001 to 0.002 mm. Hg.

The high vacuum pump works on the diffusion principle, i.e. the diffusion of gas into mercury vapour, which is obtained by heating mercury by means of a heating plate fixed on the underside of the apparatus.

Little more remains to be said about the rectifier cylinder and auxiliaries, except perhaps to point out that the selection of materials for use in the rectifier is of vital importance to avoid the danger of occluded gases being released during operation, and also to avoid porosity and the resultant percolation of air or water into the cylinder. Scrupulous care and cleanliness are also essential during assembly. A finger print on an anode is sufficient to cause trouble!

As regards outputs, these range from about 500 amps. up to, at present, an eighteen anode, 16,000 amps. unit. There appears, however, to be no reason why still larger rectifiers should not be manufactured should there be a demand for bigger units. As regards voltage, efficiency tends to limit the pressure at the lower end of the scale. It is difficult to justify a rectifier for less than 400 volts unless there are special circumstances. At the other end of the scale a limit at present cannot be foreseen. The greater number of rectifiers are in commission in industrial and traction work at voltages between 500 volts and 1500 volts. However, 30,000 volts d.c. have been obtained commercially without any indication that the limit has been reached.

Some may be inclined to ask; why this interest in rectifiers and in what way are they superior to the more familiar rotating type of plant? As far as this country is concerned, rectifiers, more especially those of the steel enclosed type, are still comparatively novel. It is only recently that it has been possible to buy a British Built steel enclosed rectifier. The advantages of this new type of plant are numerous. Since there are practically no moving parts, no commutators to be cleaned and turned up, no sliprings, no brushes, no bearings, maintenance is a negligible factor: it is practically nil. True, the life of the glass bulbs is limited—though very difficult to give a figure for—but the life of the metal type is almost unlimited. Both types run unattended. These are big points in favour of the rectifier. Finally, their efficiency, especially on high voltages and low loads is remarkable.

The losses in a rectifier are made up as follows:—

No-load losses: iron losses in main transformer; losses in auxiliary transformer, auxiliaries and excitation.

Load losses: iron losses in absorption choke or anode chokes; copper losses in main transformer, absorption choke or anode chokes; arc losses in rectifier.

These items call for little comment, excepting perhaps that referred to as "arc loss." A good deal of misconception has existed in the past on the nature of this loss. It has frequently been stated the the voltage drop between anode and cathode is constant. This proves not to be the case. Recent research shews that there is a drop of from 2 volts to 8 volts at the anode, from 8 volts to 15 volts in the arc stream, depending upon

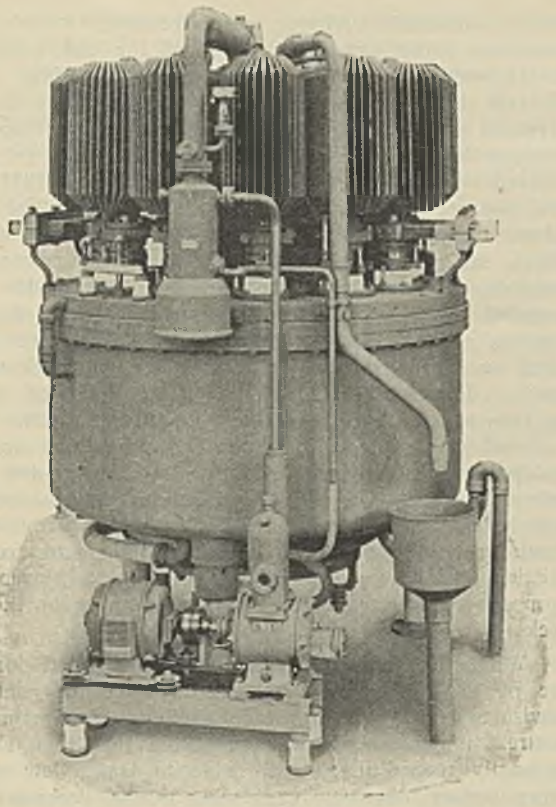

Fig. 4.—A 6400 amp. Mercury Arc Rectifier with *preliminary vacuum pump and built-on high vacuum pump.*

the degree of vacuum and the length and cross section of the arc, and about 10 volts at the cathode. The question is too involved to go into at length here, but it can be accepted that in the latest type of rectifier the total drop will be in the neighbourhood of 20 volts to 25 volts.

Since the arc loss in k.w. is a function of volt-drop and current, clearly the higher the rated voltage, the lower the value of current and therefore the lower the k.w. arc loss for any given output. It therefore follows that, unlike rotaries, motor converters or motor generators, the efficiency of a rectifier is a function of the rated voltage. Further, since the no-load losses are confined to the transformer and small auxiliaries, the efficiency curve is much flatter than in the case of dynamic plant.

Typical efficiencies for a 100 k.w., 460 volt glass bulb rectifier installations are:—

Full Load.	*¾ Load.*	*½ Load.*	*¼ Load.*
91.5%	91.8%	91.5%	89.5%

Similarly, for a 600 k.w., 500 volts, steel type rectifier, the following efficiencies might reasonably be expected.

Full Load.	*¾ Load.*	*½ Load.*	*¼ Load.*
94.0%	94.0%	93.9%	92.0%

At 1500 volts an overall efficiency of about 96.5, while at 5000 volts an efficiency of the order of 97.8% would be obtained.

The author wishes to acknowledge his indebtedness to an article "The Physical Nature of the Universe" by J. W. N. Sullivan, and L. B. W. Jolley's "Alternating Current Rectification" for much of the information contained in the first half of this paper; also to Bruce Peebles & Co., Ltd., which Company holds the British rights for the manufacture of the Brown-Boveri Mercury Arc Rectifier, for much of the information regarding the steel-clad power rectifier.

WEST WALES BRANCH.

The Mumbles Electric Railway.

C. S. JOHNSTONE.

(*Paper read 20th February,* 1932).

Though this paper is non-technical in character the author trusts that its local interest will outweigh any defects it may have on that score. Before proceeding to details of the electrification of the Mumbles Section of the South Wales Transport Company's system, it might be well to capitulate briefly the leading advantages of electric railway transport under suburban conditions. The traffic problems of suburban railways are such that electric traction is ideal for that class of work.

To compete with road transport it is necessary for the railway to have: (1) High average speed; (2) short distances between stations; (3) frequent service.

The first two requirements are obviously interdependent. The more frequent the stops the slower will be the average speed, under similar circumstances. The average speed of a train depends on three things: (1) Acceleration; (2) Retardation; (3) Distance between stops.

Dickenson gives the acceleration of steam trains as half a mile per hour per second, and of electric trains as three times this figure under similar conditions. This higher acceleration is due, firstly, to a more even torque with an electric train (the adhesion being about 25% as compared with 14% to 16% for steam, under the same rail conditions); secondly, because the motors are distributed throughout the train considerably more weight is available for adhesion; and, thirdly, to the excellent starting torque characteristics of the d.c. series motor.

The braking is an important item. Often acceleration is not complete before a train has to begin to stop for the next station, and the more powerful the brakes the longer the acceleration period can be continued and, consequently, the higher average speed can be maintained. The effect of the distance between stations is that the shorter the distance the better has to be the acceleration and braking to maintain the same average speed.

The multiple unit system is becoming practically universal for electric suburban work. The idea is to have the rolling stock in units consisting usually of one motor coach but sometimes a motor coach and one or more trailers. These units are so arranged that they can be driven from either end and can be coupled together to form a train of two or more units. When coupled together the control gears of all the units are worked together by the controller at the driving end of the train. This is effected by connecting up the control system on all cars by jumper coupling cables.

It will be seen that in addition to flexibility this system of multiple units has the advantage of ensuring the same amount of driving power per coach no matter how many units may be coupled together. Consequently, practically the same speed can be maintained during rush hours with long trains as is possible during slack periods with short trains or only one unit. Thus it facilitates the economical running of a frequent service in that no more power is used on a train, light or heavy, than is proportional to its length or weight.

Another advantage of electric traction over steam is the elimination of the necessity of the "running round" of the locomotive at termini. Less time is required to prepare an electric coach or loco. for service than for a steam engine and generally repairs are carried out more quickly. An electric train uses no power while standing in stations or at termini (this amounts to a considerable proportion of time, 30% in the case of the Mumbles Railway).

Electric cars or locomotives required in emergency are instantly available. It is possible to burn a poorer quality coal and to get higher efficiencies in the boiler of a power station than on a steam loco. These were some of the principle advantages anticipated when it was finally decided to electrify the line.

The first mention of electrification for this system was made in 1899, when the Mumbles Railway was leased by the Swansea Improvements & Tramways Company from the old Mumbles Railway Company: the lease was in fact effected with the principal idea of ultimately electrifying the line. The author cannot say whether it was a lack of capital, or doubts as to the advantages of electric traction which caused this intention to be kept in abeyance for some twelve years; but the matter does not appear to have been seriously considered until May 1913, when the whole question was looked into in detail. It was then decided that a good case could be made out for electrification and the first complete scheme was drafted. This included the building of a sub-station at the old West Cross Station. Here was to be a 1000 ampere-hour secondary battery, fed from the tramway power station at the St. Helens depôt. A new 600 kilowatt generating set was to be installed at the power station, and the switches at the sub-station were to be closed by means of pilot wires from St. Helens. The idea was to charge the battery during slack traffic periods, and to discharge it during the times of peak loads. After further consideration it was thought advisable to eliminate the battery from the scheme.

It must be remembered that this happened nearly 20 years ago, when accumulators had not reached the state of development they are in today. In a system advocated two months later it was proposed to generate three-phase a.c. at St. Helens and to transmit the current at 6000 volts to the sub-station at West Cross, where there were to be four rotary converters.

The rolling stock was to consist of seven new motor cars, top-covered, each of which was to pull three of the existing cars as trailers. That service would have been an improvement on the steam system, but it would not have been very much faster. The proposed average speed would have been eleven miles per hour. However, the whole problem was gone into very fully, and it is very probable that something would have been done, but for the outbreak of war. That caused the abandonement of the idea of electrification and so it was shelved for another nine years. It will be remembered that for some years after the War prices were high and little capital was available for enterprises of this nature.

It was in November, 1923, that the question of improving the service was again brought up. Oil-burning apparatus was obtained for one of the steam locomotives, the idea being to eliminate the nuisance of flying grit, which caused great discomfort to passengers on the top deck. The gear was never fitted, for at that time there were three other schemes under consideration. Firstly, internal combustion engined locomotives with a greater power than the steam locos. were considered. The second idea was to use electric locomotives with positive and negative overhead wires, such as are used with trolley buses. The third scheme was for electric locomotives using the rails for a return circuit. In the case of the last mentioned it was intended to use four 320 h.p. locos., pulling the old carriages. The service, although perhaps more frequent, would have been very little faster than that of the old train. It is interesting to note that, owing to the high price of steel, it was intended to use wooden poles for the overhead work. The whole thing was again postponed, it being felt that an adequate system had not yet been evolved. Three months later, in February 1924, we find two schemes under consideration. Firstly, the 1913 scheme brought forward again, with very little alteration; and, secondly, the proposal to acquire some new multiple unit system motor cars, each of which was intended to be permanently coupled to one of the old coaches. A motorman's control cab was to have been fitted on each trailer at the end remote from the motor coach. These could then have been operated either as two-car or four-car trains. In March 1924, these two schemes were still under consideration, and in addition a third alternative, much the same as the multiple unit scheme but with the difference that the control was by ordinary drum controller instead of contactors. Furthermore the feasibility of electrifying most of the existing stock was under consideration. It was not proposed on any of these schemes to cover in the top decks of the old coaches.

While the majority of the schemes called for the use of the old rolling stock, their condition made it unwise to consider their use in anything of a permanent nature. In general, it was suggested that they should be partly reconditioned and made to last a few years, being replaced by new cars when found necessary.

About that time still another scheme was brought forward in the shape of a proposal to have a sort of three-wire system. The idea was to have two overhead wires, one of which would be 600 volts above, and the other 600 volts below, earth potential. Two sets of 600 volt equipment arranged in series were to be fitted on each car. The mid-point was connected to the rails. It will be seen that all the advantages of a 1200 volt supply are obtained by this method, the running rails carrying only the out-of-balance current, which it was calculated would be not more than 5% of the total. Six hundred volts was the highest voltage for which a traction motor of the required horse-power could be obtained at that time in this country. The scheme was abandoned owing to the fear that the two trolley wires being at a potential difference of 1200 volts the necessarily complicated overhead work at junctions would prove troublesome. Furthermore, it had not been tried before, and no information was available as to the probable results in operation. At the same time it is interesting to note that it was discovered afterwards that the Southern Railway engineers had considered a very similar system excepting that conductor rails were proposed instead of overhead wires.

In October 1924, the only scheme remaining under consideration was the idea of two-car multiple unit system trains with new motor coaches and old cars made into driving trailers. The motors had, however, been increased from 65 h.p. to 100 h.p. This proposition was superseded by a proposal for making the Mumbles Railway link up with, and form an extension of, the Swansea Tramways. Tramway type grooved rails were to be laid single track from Rutland Street to the Slip, and double track from there on down to the Pier. Junction with the tramway tracks was to be made at Rutland Street and the Slip.

Two out of every three trams leaving the Pier were to run to Gower Street, and the third to Rutland Street. Sixteen new trams were to be bought; half of them fitted with 60 h.p. motors, and the other eight with 100 h.p. motors. It was intended that these should each pull one of the old coaches as a trailer. This scheme was abandoned because the small tramway type flanged wheels would not permit of high speeds with safety; and, the track being laid on sleepers, a derailment would become much more dangerous than on a street tramway. The high cost of tramway-type rails also affected matters.

It would appear that by January 1926, the idea of electric traction had been abandoned in favour of rail cars driven by internal combustion engines. One variation of this idea was to have two high powered petrol engines, each coupled to a dynamo, and made to hang under the centre of the coach. Two motors were to be fitted, one on each truck. The generators were to have very weak fields, and the train was to be started by, first, switching the motors straight on to the generators, and then, by means of a rheostat, gradually increasing the field and so bringing up the voltage. The starting switch was to be interlocked with the rheostat control in such a way that it could not be closed except with a weak field.

At least one feature in this scheme was very attractive. The acceleration would have been superior to any constant potential system. The current passed through the motors on which the torque and acceleration depend would not have been allowed to fall away so rapidly with the increase in speed, as is the case where the final voltage is limited to a constant supply. The load on the engine being proportional to the output of the generator in watts, would be comparatively small until about half speed was reached. It was anticipated that special precautions would have been necessary to prevent commutation trouble when the generators were working with very weak fields. This idea had a very short life, and was not investigated very deeply. From this time the present scheme in its initial stages held the field. However, in June 1926, we still clung to the idea of using the old coaches as trailers, and having first and second class. These two items were not finally ruled out until about October 1927, when the system ultimately adopted had started to come into being.

The old steam railway was worked under the regulations governing Light Railways (The Light Railways Act of 1902). That is to say, no signals were used and the maximum speed was under 25 miles per hour. No continuous brakes were necessary.

The present system employs an automatic block signalling system and permission has been granted for a maximum speed of 30 miles per hour, with the exception of certain places such as in the town, where there are roads crossing the line. An air brake acts on all wheels in the train.

The rolling stock consists of thirteen double-deck coaches, each seating 106 passengers. The stated voltage is 675, and the cars are equipped on the multiple unit system with magnetically operated contactors. Each car is fitted with two 60 h.p. 675 volt traction motors, which give the cars a maximum speed of approximately 28 miles per hour. They are fitted with straight air brakes with emergency feature.

An interesting item in the cars is the door gear. the doors are worked by compressed air, and are controlled by push buttons in the driver's cab. All doors operate simultaneously, and interlocks are fitted, so that the train cannot start until all doors are completely closed. The controllers are fitted with "Dead Man's Handles" and these, when released, in addition to cutting off the power, and applying the brakes, release the doors, enabling them to be readily opened by hand.

The cars were tested and the motormen trained during the six months previous to the starting of the electric service. The air door gear was fitted on the cars at Swansea partly by the Company and partly by the makers.

The overhead system is unique, combining as it does the cheapness of the tramway type suspension with the flexibility of a catenary system.

With the present service a trip is done at an average speed, including stops, of about 18 miles per hour; the average speed throughout the day is 13½ miles per hour. Figures for the year 1930 shew that during that period 323,000 car-miles were run, and that the delays amounted to less than 0.4%.

A car is considered to be delayed if it does not run, or is more than one minute late. Over 30% of these delays were due to causes not connected with the electric working of the line.

One passenger class only is provided; an innovation which has proved to be entirely successful. With the present system nearly 2500 passengers can be carried per hour, which is the same as the original figure, suggested in 1913. Some idea of the accuracy to which an electrical engineer can work is given by a schedule calculated in 1924 for the Mumbles Railway. The figures obtained for the time taken to do one journey were 19 minutes and 11 seconds in one direction, and 19 minutes and one second in the other. The present schedule time is 19 minutes; the error in one instance being 0.9%, and in the other 0.088%. This represents an average of less than a half per cent.

Perhaps the most interesting item on the cars from a mechanical engineering point of view is the fact that when the cars are fully loaded, the pressure on the axle-box bearings is over 600 lbs. per square inch. There was considerable trouble with these bearings, but now they run very well; the author believes that it is usual, when designing a bearing for this class of work, to allow for a pressure of about 350 lbs. per square inch.

The signalling system is entirely automatic. Each length of single line is fitted with block signals, which are operated by the cars when they pass under special contacts fitted in the overhead gear. A car approaching a length of single line passes under an "on" contact: if the signal facing the car is at "all clear," a red disc moves up at the far end of the block: immediately this red disc is up, and locked in position a switch connected to it is operated, which brings up a white disc at the end nearest to the entering car. When the motorman sees the aspect change from a blank to white he knows that he has put the signal "up" at the far end, and can proceed with safety. It is to be noted here that the man must actually see the white disc go up in front of him before he can proceed.

The car, when leaving the block at the other end, passes under an "off" contact, and the red disc is de-energised, unlocked and allowed to fall. When it falls, it cuts off the supply to the white at the other end, which falls also. Working in conjunction with the block signals are point indicating signals which face the cars as they approach all facing points. These point signals consist of lamps behind a red lens and a green lens. When those behind the green lens are alight, it tells the motorman that the points are locked and are not open more than about $\frac{1}{16}$ inch. If the spring fails to close the point completely, or the lock fails to catch or is broken in any way, the red lamp is lighted up. If both lights are out (as they would be if a lamp burnt out) the motorman is instructed to act as if they were at danger.

WEST OF SCOTLAND BRANCH.

Ⓟ Reconditioning Electrical Apparatus.

ROBERT KIDSTON.

(*Paper read* 17*th February*, 1932.)

In reconditioning electrical apparatus several questions have to be taken into consideration, for instance, (1) what material may be saved and used over again? (2) can any improvement over the former method employed be adopted? (3) can a different class of material be subsituted without in any way impairing the efficiency of the apparatus and at the same time effecting a reduction in the cost of repair? Let us take as an example the case of armatures sent for repair. The report from the colliery says "burned out: to be rewound."

If the armature is a small one, wound with circular wire, either single or double cotton covered, there is no economy to be effected in trying to save any of the coils for using over again; some of the coils may seem all right, but, having been scorched by adjacent coils, the insulation is not to be depended upon and may crack up when being reassembled and cause needless and unnecessary work.

In the case of larger types of armatures, say for coalcutters: and if they are wound with rectangular or strip copper, it is quite possible to use most of the coils over again. The method adopted is this. When the armature is being stripped the coils are each marked separately by the means of small number types, the numbers starting at one and running consecutively till the last coil has been marked. The reason for this marking is that the coils, when being reassembled will, obviously, all be of sufficient length when joining up to the commutator lugs. The coils are usually composed of three or four turns taped together, and being of different lengths to lump the loose coils together without method is merely to create trouble when rewinding. After the coils have been numbered they are usually given to the boys who strip the tape off them and, if they have been badly scorched through excessive heating, they have to be scraped in order to clean them up ready for retaping. The old method was to tape these coils by hand which was a most monotonous and tiring job. This method used to take three boys a week to tape one set of coils, but with a taping machine motor-driven and fixed on a bench at a convenient working height, as shewn in Fig. 1, one boy can do the same work in a matter of two days.

In the case of forming armature coils, these were usually made on formers of the type shewn in Fig. 3. These are wood formers and where a large number of different types of armatures were repaired, it entailed carrying a large stock of formers for each class and type of armature. Moreover, this method of making coils depended a good deal on the skill of the workmen as to whether it was a neat job or not. In the first place the coil was wound on the former in the shape of a loop (a): this was bound by small fixings at points to keep the wires in their proper places and (b) they were then taped: after which (c) the evolutes were formed, usually in a bench vice the jaws of which were protected by presspahn or other material: and finally (d), the parallel sides of the coils were measured off and drawn out between two pieces of wood fixed in a vice. It will be readily understood that much time is taken to perform all these different operations and, when all is done, it is impossible to get all the coils alike.

In place of the above method of forming coils a machine is now on the market which winds, shapes and finishes a coil all in one operation. The *modus operandi* is as follows. The wire for making the coils, depending on the number of layers, is taken through the wire guide to the fixing block on the machine; after being given one complete turn the holding block is taken off and the wire fixed to its own clamp. The coils are then wound the proper number of turns, after which they are bound together at intervals to keep the wires together. The two side supports are slackened off, which allows them to slide along the guide bar, during which time the right side foot pedal is being depressed and the evolutes and length of sides of coil are being formed. A stop on the machine prevents this fixed position from moving and when the correct distance is obtained the coil clamps on the top side are loosened and the coil lifted out. Another feature about the coils is this: every winder knows the difficutly sometimes encountered in trying to get the coils into their slots: this machine gives each coil an angular twist which makes it very much easier to enter the coils in their slots. Furthermore, all the coils being symmetrical helps to give a better balancing movement to the armature and also to give it a much better appearance when finished. Coils for 1½ h.p. up to 50 h.p. armatures have been made on this machine without any difficulty. The number of coils wound per hour so far has been fifteen, but this figure will be improved upon as the machine becomes better understood.

Insulating of Armature Coils and Core Slots.

It has been found that better results are obtained by giving the armature coils themselves an additional lapping of empire tape prior to their being taped with cotton tape. The empire tape has the advantage of giving a better protection against dampness than the cotton tape, which is usually varnished some time before assembly in the armature but often not until the whole job is finished. The better course is to impregnate the wire itself before the coils are made. For insulating the slots it is better to use one or two thicknesses of insulation rather than one heavy one because there is

Fig. 1.—A Motor-Driven Taping Machine for Armature Coils.

Fig. 2.—Winding a Brake Coil for a Hoist.

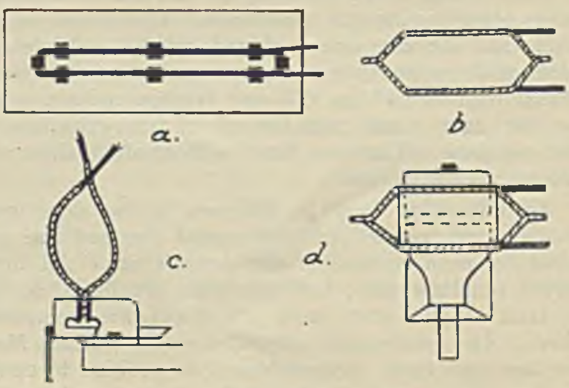

Fig. 3.—The winding of coils by means of wooden formers.

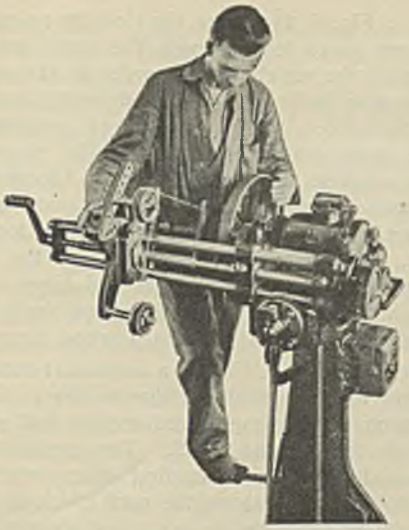

Fig. 4.—A Winding Machine for Field Coils, etc.

Fig. 5.—Automatic Coil Winder for small coils.

always some protection if one layer should give out. For this purpose there is now on the market in sheet form an insulation consisting of two thicknesses of leatheroid interleaved with one piece of empire tape between: by using this the time formerly taken in cutting off the different pieces of insulation is now saved.

Repairs to Field Coils.

Those familiar with repairs to field coils, and having to wind them by means of hand or the use of a lathe, will know the difficulties which have to be contended with. Some of the troubles are: the time taken in starting and stopping; the devising of some form of straining device; the care of keeping each turn in its proper place, which is usually done by the operator's hand: the difficulties encountered when unwinding. In these days of amalgamations and the taking over of smaller concerns by the larger firms there is bound to be a lot of time lost in passing an order from one department to another before it finally gets to the proper quarter: and even then the colliery engineer, after having given all particulars, is asked if he can send the works a sample. Here is one instance of the kind. An order was placed with a firm to supply four shunt field coils for a small $\frac{3}{8}$th h.p. motor; after having given all nameplate details of motor and a few letters asking when we might expect delivery—luckily there was a spare motor—delivery was eventually accomplished after a wait of no less than five months.

In another instance, two field coils for a coalcutter motor were ordered; the same type of coils had been supplied for years without any complaint or difficulty, but on this particular occasion two coils were received which would not fit on the pole pieces, in fact they were so small that it was impossible to get them even entered on. Upon writing to the firm telling them about the coils the answer that came back was a request that we should see if there were not two or three layers of adhesive tape on the pole pieces! There is no necessity to indicate here the nature of the comments made by men who had used that same type of coil for years and had to suffer an insulting challenge. Is it any wonder then that those responsible for the repair and upkeep of a large number of motors should endeavour to find some method where time could be saved and where it would be possible to ensure that the coils would fit without any trouble and so, also, to keep costs down to the very lowest?

As a result of experiences of the kind indicated it was decided to install a coil winding machine capable of taking in the largest size of field coils including coalcutter coils. The machine which was chosen is the one shewn in Fig. 4. It will be observed that the machine is compact and takes up very little space. It is driven by a 2 h.p. motor with a three-step cone pulley which gives the spindle speed of 18, 33 and 66 r.p.m. A friction clutch with foot pedal is attached to the supporting pedestal so that the machine can be started and stopped almost at once. The machine is also geared to suit the winding speeds of wires from 0.0076 in. to 0.232 in. and a card shewing the different ratios of gears is provided. Another arrangement also incorporated in this coil winder is one to keep each wire in its proper place; this attachment has a hand clutch which can be thrown out of or into gear at will; when this has been set to its proper place, all that is required when winding a coil is—as the wire reaches the side of the coil former the direction of this feed is reversed by a small handle on the machine. A straining arrangement is also used which keeps the wire under tension, and mounted also on the machine is a counter which automatically registers the number of turns wound by the machine. A reversing switch has been fitted to the machine which is very useful for unwinding purposes. A set of four coils similar to the small coils for the $\frac{3}{8}$th h.p. motor previously referred to were made for a small portable coal boring machine in two hours' time and gave every satisfaction. Practical men will readily understand what a benefit this machine can be when it comes to a case of a rush job. All coils for coalcutting machines are now wound on this machine and in order that no mistake may be made in the finished sizes of coils a dummy pole piece is used upon which every coil can be fitted before leaving

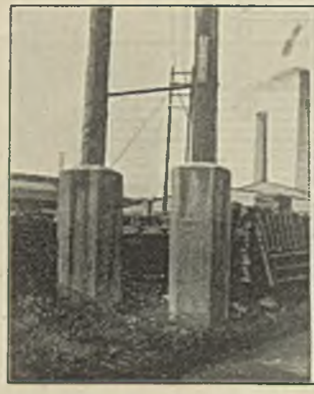

Fig. 6.—Shewing method of strengthening defective poles.

Fig. 7.—Method of repairing broken limb of a two-member pole.

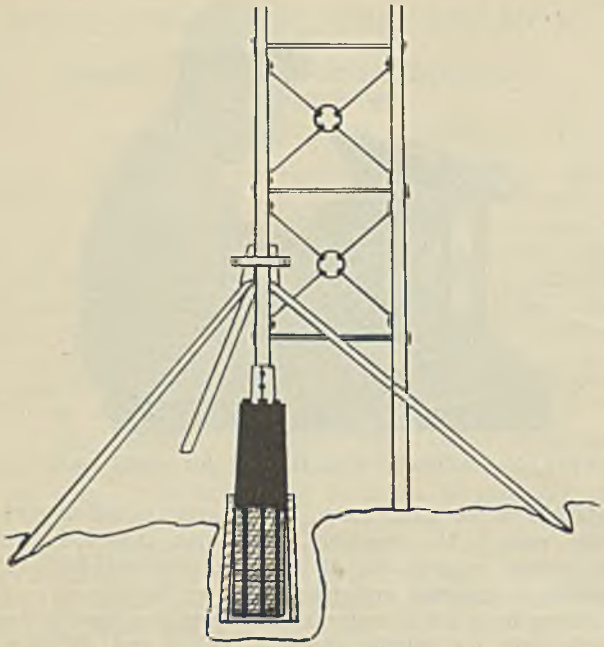

Fig. 8.—Details of the repair shewn in Fig. 7.

the workshop as a finished part. In addition to the coils already mentioned compound wound field coils have been made for a 60 h.p. motor, and a complete set of coils for a 15 k.v.a., three-phase lighting transformer, 2000 volts to 200 volts. A set of stator coils for a small three-phase, two h.p. squirrel-cage motor have also been made. Whilst the advantages of such a machine must be apparent to every one, the author should mention that this machine has only been in service for a few months and appreciates with satisfaction that its full possibilities have not yet been explored.

Renewals and Repairs to Poles and Overhead Mains.

The following two illustrations are intended to shew what was done to preserve poles which, owing to the confined space they were in and due to the fact that the power supply could only be cut off for a very limited period, called for exceptional methods.

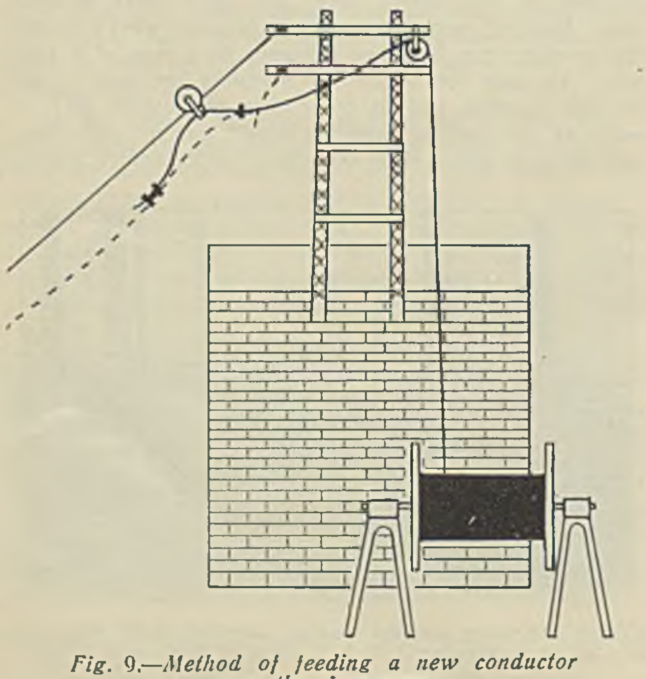

Fig. 9.—Method of feeding a new conductor over the river span.

In No. 1, Fig. 6, the outer shell of the poles was beginning to rot away leaving only the inner core of the pole to take all the weight, so, in order to strengthen the pole a box was built round the defective part. The whole of the outer rotted tissue was removed, some heavy wire mesh was formed round the cleaned pole, after which concrete was poured in and allowed to set; when this was sufficiently hard and the wood box taken off a surface coating of cement was given for appearance's sake. The part of the pole above the defective part was bored in one or two places and given a soaking of creosote in order to preserve the wood the bore holes were afterwards filled up with hard wood plugs.

In the case of No. 2, Fig. 7, a somewhat more drastic operation had to be carried out due to the fact that one of the poles on the two membered section had given way altogether at the ground level. The method adopted here was as follows. In the first place bracing bolts were fixed to the poles above the part which it had been decided to cut off in order to make a more rigid fixture. Then at a height above the affected part a gland was bolted round the pole, see Fig. 8, from under which battens were used to support the top part of the pole while the bottom portion was cut away. After the pole had been cut, a long tubular gland was bolted round the pole, the gland had flanges at its base, and through holes in the flanges were hung long bolts or anchors which were cemented in with the lower pillar of concrete which had been formed to take the place of that portion of the pole which had been cut off. Both these operations were carried out without the power supply in any way being interrupted. It is to be noted that there has never been a shut-down or any loss caused through power being off on this section of the line for a period of more than twenty years, hence the reason why such unusual methods and devices had to be adopted.

Another instance was one where three conductors cross a river. One conductor had become badly burned in places and the outer strands of the conductor which was a 37/0.072 wire, were beginning to fray out in the span over the middle of the river. This had been caused at one time by the striking of a barrel or U-shaped wire guard, surrounding the wires, due to the prevailing west wind and this conductor, which was one of the bottom two, received all the damage. At first a method to prevent the guard striking the wires was tried, this was to fix rubber discs round the two lower conductors, but this was found not to be practicable as a proper means of support for the workmen fixing them could not be obtained owing to the sag on the wires and due to the difference in height between the two supports, one side was about 90 feet high and the other side about 30 feet high: the old guard, which was getting badly worn, was eventually taken down altogether and a new one of a different form put up underneath the wires; the new guard consists of two parallel wires with cross supports between and it is still in satisfactory service. Alarm was being felt at the state of the conductor on the west side, so it was decided to renew this, and the following method was adopted. By the way, it should be mentioned that these wires cross over a roadway, four sets of rails and a telephone route inside the works, and outside a public roadway and the River Carron. It was decided then to feed a new conductor over all these obstacles using the top wire as a means of support and the wire to be taken down as a draw wire: this was done as shewn in Fig. 9. On the top arm was hung a shackle pulley and the new wire, which was sitting on a trestle on the ground was passed through this. The defective wire was then slackened off at the opposite end and a length of rope fastened to it to allow enough slack to be taken back, this wire was then cut off at the shackle insulator and fixed to the new wire through the bottom of the shackle pulley (which was suspended from the top wire) by a wire rope clamp on either side to make sure that neither could slip. It was then a simple matter to pull the new wire across. After this was safely across it was made off first at the high pole then strained up from the lower pole. This job which was done at a week-end in a continual downpour of rain was finished in a matter of four hours; this time included setting up of tackle as nothing could be done until the supply was cut off. The illustration, Fig. 10, shews the river crossing span completed.

Rewinding a 15 *k.v.a. Transformer* 2000 *v. to* 200 *volts.*

Before referring to the winding of this transformer, it will be interesting to consider what was probably the cause of it burning out. The distribution board on the low tension side is of a dual type, as shewn in Fig. 12. The idea of this arrangement was to use it as a three-phase board with the circuits balanced across the phases, or as a double-pole d.c. board. The reason for this was that at one time the supply was d.c. taken from a small motor-generator set when the pit was in operation, and the transformer was installed during a breakdown of the generator and thereafter retained as a spare, but when the colliery closed down the transformer was regularly put on circuit and left pretty much to the tender mercies of a night watchman. The switchboard in its original d.c. state was equipped with one voltmeter and one ammeter and they were all that was necessary to tell the voltage and see what load was being taken from the generator; but when the supply was taken from the transformer the ammeter was connected in Phase A and thus indicated the load across Phases A and B, plus the load on A and C, but took no account of the load across Phases B and C. There was therefore no proper indicator as to what the load on each phase was; some of the phases were bound to be overloaded and in course of time burn out, which was exactly what did happen eventually. One phase was burned out; it was disconnected and a single phase supply taken from the other two until such time as the coils gave way altogether, when a rewind became necessary. The transformer was sent to the workshop, dismantled, and the necessary particulars such as size of wire, number of layers and turns and the method of insulating coils taken. A wood former was made and the three units, each consisting of the H.T. and L.T. windings, were wound and taped after which they were dried out in a drying oven, then immesred in an oil and acid resisting varnish, allowed to dry, mounted on the transformer core, connected up, tested for insulation and the voltage taken. The test was made by using the transformer as a step-up one. The workshop voltage, which is 200 volts single-phase, was connected up alternately between the phases, and a Kelvin electrostatic voltmeter capable of measuring up to 6000 volts was used. The voltage was found to be in order so the transformer was taken to a supply corresponding to its particular voltage which was 2000 volts on the primary side giving a voltage of 200 volts on the secondary side. (Fig. 11.)

The transformer after being on circuit for about an hour with a very light load became very warm. The load was disconnected from the secondary side and the transformer again switched in with the secondary on open circuit. After being on circuit for about two hours the heating was just the same as with the secondary on load. Investigations as to the cause of this heating eventually indicated that when the coils were being wound the earth shield between the primary and secon-

Fig. 10.—*The river crossing after completion.*

Fig. 11.—*The re-wound transformer ready for replacing in the tank.*

dary windings, which consisted of sheets of tinfoil instead of having a gap left, had been put on as one continuous layer or ring, thus forming a closed circuit.

This oversight of a well-known principle may be briefly followed for the benefit of those who may not realise its great importance in all alternating current work. An example of what took place with this metallic shield might be taken as follows. This takes the form of a laminated core on which is wound a coil with the iron core projecting beyond the coil (Fig. 13). On the top of this coil is placed a metal ring. As soon as an alternating current passes through the coil the ring springs upwards and floats freely in the air, and gradually gets very hot. The facts of heating and motion prove that a considerable current has been induced in the ring also, the repulsion of the ring shews that the current is induced in it as being opposite in direction or polarity to that of the coil: precisely similar to the interaction between the primary and secondary of a transformer. The e.m.f. induced in the solid metal ring, which has a very low electrical resistance, can produce an exceedingly strong current and this expended in heat causes the ring to attain a very high temperature. Similarly, for this reason,

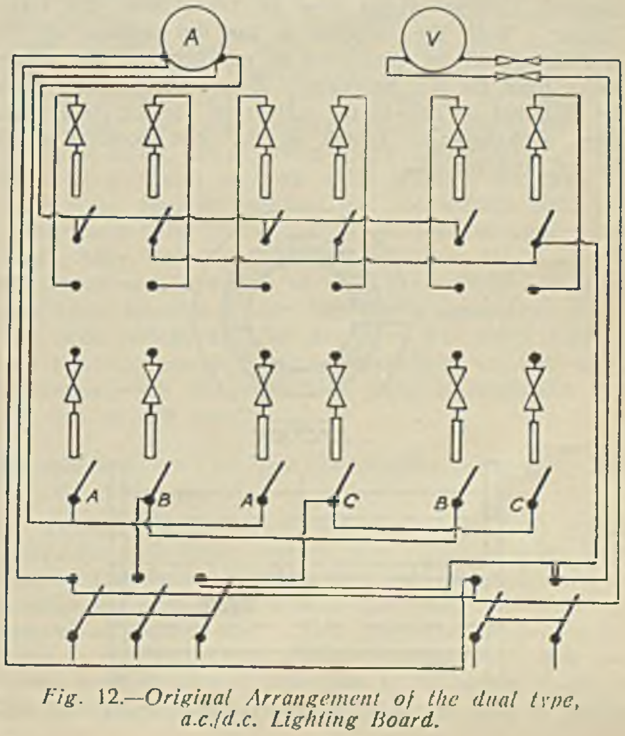

Fig. 12.—*Original Arrangement of the dual type, a.c./d.c. Lighting Board.*

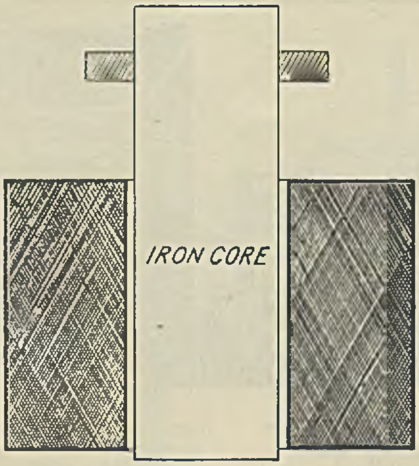

Fig. 13.—*Laminated Iron Core with Coil and Ring.*

metal bobbins for alternating current magnets must never be complete cylinders: they should be made with a slit as shewn in Fig. 14, so that the bobbin itself cannot serve as a short circuited secondary winding. No part of a transformer exposed to the changing magnetic field must be made of solid iron because it would be dangerously heated, that is why transformer cores, stator cases and armature cores are all built up of thin laminations.

Reverting back to the original L.T. distribution board a better plan would have been to connect up the board as shewn in Fig. 15. This shews a board with six circuits, three on top and three on the bottom. If each of these circuits was provided with a D.P. change-over switch a much better distribution of the load could be obtained, for instance, No. 1 on the top could be joined to No. 1 on the bottom, say phases A and B. No. 2 on top with No. 2 on the bottom with phases B and C and No. 3 top and No. 3 bottom with phases A and C. An ammeter could be coupled in each phase, thus giving a full indication at any time of what load was being taken. Thus, when the switches were in the down position current would then be taken from the transformer. With the switches in the top position all the circuits would be connected in parallel and the supply taken from the d.c. generator. A separate ammeter could be installed or one of the meters on the a.c. side could have a change-over switch so that one position would be a.c. and the other d.c.

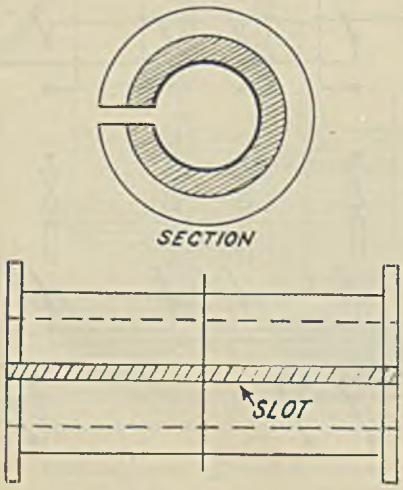

Fig. 14.—*Split Bobbin for A.C. Coils.*

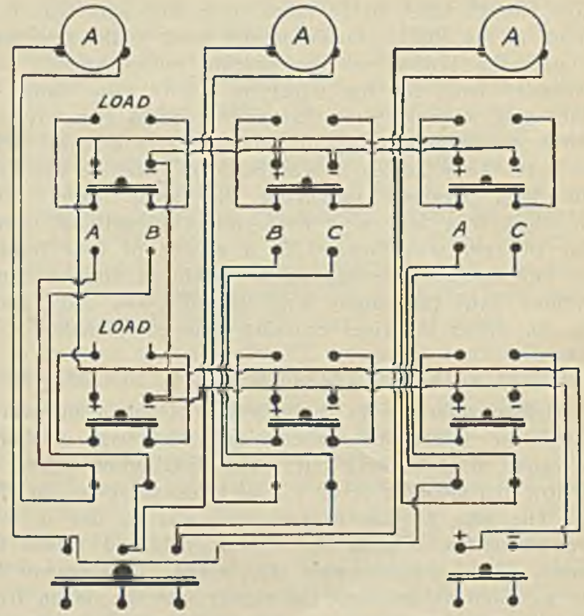

Fig. 15.—*New Arrangement of a.c./d.c. dual type Lighting Board.*

Squirrel-cage Rotor Troubles.

Induction motors are less liable to breakdown than direct current motors owing to their simpler and more solid construction and to the absence of commutator and brush troubles. The conductors of a squirrel-cage or short circuited rotor generally consist of bars or rods of copper placed in slots in the core, the ends of these bars in some cases being bored and a screw from each bar fixed to the short circuiting ring. The author has quite a number such as this and the screws in a good many cases up to motors of 22 h.p. are only $\frac{3}{16}$ inch in diameter. These screws eventually work loose and when this occurs bad connection is made and, as the current generated in the bars, has to circulate in the end rings heating is bound to take place; the result is that the motor slows down and fails to take its proper share of the load. Instead of using screws to hold the ring and bars together a better method is to braze them together or to cast a solid gun-metal ring round the conductors. This has been done with several of the motors and since then they have given every satisfaction: it has been well worth the time and trouble spent on this work.

Repair to 50 *h.p. Three-phase Slipring Motor.*

The following illustrations shew what happened to a motor whose position was such that it was impossible to see properly the working conditions. The motor is placed in a hole beneath the ground level, where there is no room to get a proper inspection made, and on top of this is a plate which requires two men to lift and which carries a small track for works' bogies. When the man responsible for oiling this motor comes along what happens is this—he cannot see the position of the oil level properly, so he just gives it some oil whether it requires it or not. The not inexcusable reason being that if anything goes wrong with bearings, perhaps through an oil ring jamming, he can say: "'well it was'nt for the want of oil, anyway." The illustration, Fig. 16, shews the result of over-oiling combined with the condition of the iron dust of the shop mixing with the oil and gradually settling on the windings until the cotton tape and the slot insulation became impregnated. Naturally, a fault developed and caused a blowout in the stator core. The insulation of the slots had been poor in the first place, there being only a tube of leatheroid without any other protection to the top of the slot. This was further aggravated by the fact that the motor at one time had been down in the bearings, and the rotor had fouled the stator core, thereby scoring the windings. Before this repair was completed five new coils had to be inserted. When these were all in place each slot was protected by a fibre wedge which ensures that no oil or dust can get into the slots (Fig. 17).

With regard to the position of this motor, it appears to be a fallacy among some mechanical men that any place is good enough for a motor; consideration is given to the mechanical side to secure accessibility in case of repair, but the electrical end, particularly the motor, is given no consideration at all: in a good many cases no provision is made even for lifting out the motor; perhaps this may be taken as shewing the unbounded faith and confidence placed in the motor as once it is installed it is supposed to be good for many years' service without any fear of breakdown. It is, in fact, agreed that with a motor, properly protected in the electrical sense, there is no reason why it should not give many years of service with the minimum of attention.

In most cases where motors are started by a certain individual the motor gets some measure of fair play, but where Tom, Dick and Harry are starting motors, some protective device is called for in order that the proper starting sequence may be adhered to. In some type of star delta starters for squirrel-cage motors one method adopted is a stop which prevents the handle being thrown beyond the starting position, and when the motor has attained speed the starting handle is released by a spring catch which enables it to be put into the running position. Protection is usually provided by means of overload coils and no-volt coils. One objection to the fixed handle type is found sometimes when a motor is overloaded through faulty bearings or by the shafting getting out of alignment; when this happens, instead of removing the cause which trips the switch, due to the overload, some misguided persons will tie back the handle, often with dire results to the motor. This happens sometimes with those d.c. starters provided with a handle which is moved over the resistance studs until finally it is held in position by a hold-on coil. At some time this coil may be burned out and instead of a new one being inserted the handle is tied back. On one occasion the author had to visit a certain motor driving a pump in one of the collieries; the motor was provided with a high-grade starter of the type mentioned, and on the handle of this starter was a collection of rubber joints and iron washers. On asking the attendant what was the idea of having them there, he replied that it was a handy place to keep them! However, on removing them, their true purpose (a restraining weight) was discovered. Instead of the fixed handle a better plan is to adopt a ratchet movement which ensures a certain time interval between successive steps; this type also is usually provided with a free handle which eliminates the possibility of tying in the handle and defeating the purpose of the overloads and no-volt coil. This principle applies of course to rotor starters for slipring motors as well as to starters for d.c. motors. Instead of the older forms of starter, it is best to install the modern contactor types arranged for push-button control. The contactor gear can be locked and only the push-buttons for starting and stopping the motors are normally accessible. There is no excuse for retaining old and obsolete types of starters in service now that there are so many reliable types which are trouble-free.

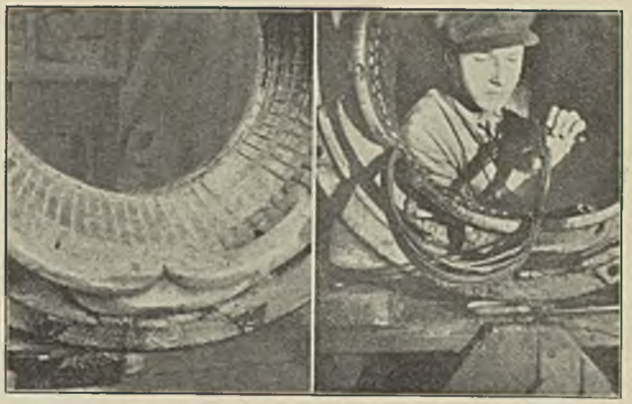

Fig. 16.—The conditions inside the motor through excessive oiling.

Fig. 17.—Removing faulty coils from the motor shewn in Fig. 16.

Converting Old Open-type Coalcutter Armatures to suit Enclosed Type of Coalcutter.

Having quite a number of old open-type coalcutter armatures lying about since the machines had been scrapped, it was decided to make use of these and convert them into enclosed type armatures. First of all the armature winding was stripped and the commutator taken off. Four bolts were made, flattened out to fit the armature slots and screwed at either end, these were fixed with semicircular pieces of flat iron at either end of the core to keep it in place when the shaft and hub were taken out. This was done by means of a hydraulic press. At one time the press used was a vertical machine for pressing cement into embedded type hotplates for electric cookers. Though, in its original state, it had only a travel of about a foot it was decided to use it for pressing armature shafts out and in. The press was dismantled and two 3 ins. spindles fitted whose lengths were long enough to take in the largest type of armature in service. The head piece carrying the ram was bolted to the wall and placed as for horizontal use. The pressure available on this particular press is 50 lbs. per square inch. An average pressure of 20 lbs. per square inch is necessary, if this is exceeded it has been found that something may crack or fracture, and when fitting shafts which require more than 20 lbs. pressure these are taken out and slightly reduced in the lathe. The shaft is turned down to a fine sliding fit and forced in at a steady and even pressure. In some places the only means of taking out or fitting shafts is by use of a heavy hammer: a clumsy method which is often the cause of broken and cracked armature and commutator hubs and which must have serious effects on the armature windings. After the shaft and hub had been taken off the old armature a new hub of high permeability cast steel was fitted, likewise a new shaft and a commutator which had been re-lugged. The armature was then rewound and put into service. In this way three or four good armatures were recovered from scrap at practically half the cost of new ones.

Rewinding 55 h.p., 500 volt, Three-phase, 50 cycle, Slipring Motor Stator.

General Particulars of this motor are: 18 poles; 320 r.p.m.; 216 slots; size of wire, 0.575 × 0.06; bare copper strip, four conductors per slot; 16 conductors, or 8 coils, per pole phase group; step from slots 1 to 13; connection, series star. This particular motor which drove a compressor for a sand blasting plant had had to be repaired several times due to the pellets used for the sand blasting operations being blown into the motor

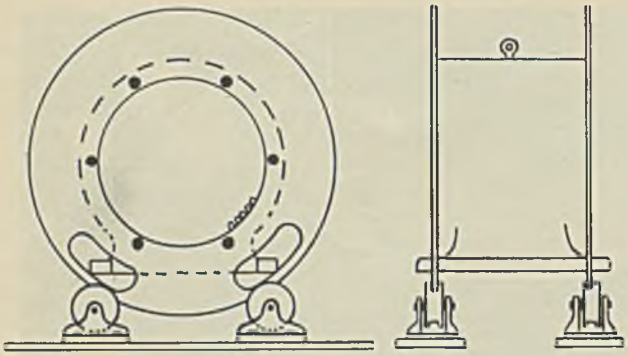

Fig. 18.—A motor with flanges bolted to it and mounted on rollers to facilitate easy turning .during repairs.

through a defective fan casing and causing shorts between turns.

As the motor had been in continuous service night and day for a period of thirteen years the insulation had deteriorated to such an extent and become so brittle that it was a risky job when a repair was effected, as the insulation on the coils adjacent to the damaged ones was liable to be fractured at each repair.

It was, therefore, decided to rewind the machine, at a holiday period as no spare motor was available and it was imperative that it be kept going. The normal duty is that 130 baths are sand blasted every day with this sand blasting plant and so it would be very serious should anything go wrong with the motor. The stator was first brought to the workshop, large circular flanges were bolted on to either side by means of the bolt-holes for the end shields. The stator was then lifted and set on four flanged rollers to facilitate easy turning and to save the necessity of shifting it by tackle to a different position when the rewind was being effected (Fig. 18). By this means the workmen were able to work in the one position and at a convenient height. The turntable itself was the means of saving a few hours on the job. The conductors were, first of all, unsweated: these had been soldered together in pairs by means of clips and, due to the above method of the turntable being adopted, it was possible to employ four men at this part and still not be in each other's way. The next part was to withdraw the conductors from the slots and, owing to the shape of these coils being bent at an angle to the slots, all the coils at one side had to be straightened out in order to be able to pull them out of the slot. All the tops were first withdrawn and each numbered by a small number type. The same method was adopted for the bottom coils. All coils were kept separate and they were then given systematically over to the boys to have the tape stripped off them; they were then turned at the ends, after which one of the boys retaped them on the taping machine shewn earlier. In addition every end coil of a phase group was further insulated with empire tape at the part outside the slot.

The next operation was to go round each slot and see that there were no burrs in any of them likely to damage the slot insulation. The plot insulation consisted of micanite tubes, and it was here that the first real difficulty was encountered: the tubes had been supplied by the makers of the motor and, when everything was ready for inserting them it was found they were too big for the slots—even with the application of heat it was found impossible to fit them. The remedy was found in an alternative and tubes were made of leatheroid in an alternative and tubes were made of leatheroid with empire tape between. This, of course, took some time, but the author considers that the tubes fitted are stronger mechanically than those of micanite and will give many years' service. The conductors were then fitted into the slots in the same order as when taken out. As one end of each conductor had been left with the original set in them it was only necessary to set out the other end to the proper distance. Extra insulation had however to be put on every end coil of a phase group as it was not possible to get them through the slots if this had been done previously. It was then ready for re-soldering and after this had been done the connecting leads fixed and brought out to the connection block. There is one point to mention here where the manufacturers might assist maintenance men and that is, instead of joining the star connection inside the motor usually in some inaccessible place once the motor is assembled, they could bring the ends out singly and connect them to a common bar on the connecting block: that simple change would facilitate testing and save a great deal of time. The same applies also to d.c. motors and it would be a great advantage if a connection block were fixed on each motor where the necessary changes could be made instead of having to dismantle part of the motor. Some makers do adopt links for the purpose and that is quite good. In this particular instance the three ends were brought out to a common junction. The stator after having been tested was taken to a large drying-out stove and kept there for about ten hours. It was then sprayed with impregnating varnish, and returned to the stove once more to be thoroughly baked; it was taken out, allowed to dry and given a coat of finishing varnish. The machine was assembled in its place, put on load, and has now been in service for over a fortnight, working two shifts each day, and is giving every satisfaction. The total time taken for this repair from the time the motor was dismantled till it was in service again was six days. There were only two journeymen on the job, one on dayshift and one on nightshift, the rest being boys from 1st year to 4th year apprenticeship: three altogether on nightshift, and five on the dayshift.

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Transmission Line Construction.

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General Considerations.

The object of this paper is to outline briefly the procedure in the construction of transmission lines. The construction of a transmission line differs from most other engineering undertakings, because of its continually changing location, the topography of which may be made up of plains, valleys and mountainous districts in which there is a considerable difference of elevation. The geological conditions along a line often change and although geological maps enable one in a general way to form an idea of the subsoil conditions, experience proves that for exact data of local formations trial borings are essential.

The season of the year in which the work is to be done naturally affects progress and efficiency. It affects costs too. Cold and rainy seasons influence supervisors and workmen alike and morale and team work often suffer. What are bad roads in the dry seasons may be impassable in the winter, with the result that transport hauls will be longer and more costly or wholly impossible to achieve. Construction on marshes that are approachable in summer and on which engineering activities are then possible, may well have to be abandoned later in the year. The months of greatest efficiency and commercial value in transmission line work are the summer months.

It is safe to say, of this country at least, that one of the most difficult stages is in obtaining rights of way and wayleaves. There is nothing more calculated to disorganise construction work than the absence of these facilities at due time and in their proper sequence, except it be their withdrawal when once given.

Much of the construction work is skilled and it takes some time to get together an organisation that is efficient and progressive. There is what may be termed a "weeding out" process of employees before the organisation develops smooth running and high production. In the event of complete interruption, or a slowing down of the programme of construction, the unavoidable burden of expense rises very rapidly. Statistical evidence on this point is indisputable.

Construction Costs.

The financing of construction work must be carefully considered, so that the capital invested is economically employed and placed on a productive basis at the earliest moment, and the interest on capital always kept at a minimum. The investment of capital on construction and the planning and scheduling of the work to be done must be jointly considered. Estimates of cost must be prepared for design and erection and so on, and the ordering and delivery of material at specified dates secures economy. Sufficient information must be obtained in advance to enable study and design of foundations and structures for special locations and obtaining the required plant. The field organisation is planned well ahead of the construction period and anything likely to upset the normal arrangements may well throw on it a burden of expense that is difficult to reduce or remove. In all phases therefore, close co-operation is not only important but vitally essential.

In the event of delay, day-to-day labour may be dismissed and again engaged when the work re-starts. The same men may, however, not be obtainable and there is a consequent loss of efficiency while crews are trained and before production again returns to normal.

Reconnaisance and Survey.

One of the first duties of the engineer will be to collect information regarding the physical features of the country to be traversed. A census or estimate of the probable electrical requirements of the districts passed through will already have been made. The information to be sought at this stage will include:—

(1) General Features: that is, the general positions of rivers, roads, railways, valleys, hills, woodlands etc.

(2) Geological Features: that is, the character of the soil and the subsoil and the inclination of the strata.

Armed with a pocket compass for ascertaining directions, an aneroid barometer and hand level for obtaining approximate elevations, the observer will estimate distances by the eye, but a pedometer will be an aid. The amount of work that it is necessary to expend on reconnoitring at this stage, will depend on the character of the country and the importance of the project. It is, however, unwise improperly to economise as a careful exploration will save much future expense.

The observer with an acquaintance of the system controlling topographical configuration will very much lessen the time and labour he expends on reconnoitring. The earth's surface is divided into two main classes, namely, hills and valleys. The watercourses should be observed, for they are nature's way of indicating the high and low elevations of the surface. They mark the lines of greatest longitudinal slope and the approximate course of the hills.

Preliminary Surveys.

On the completion of the reconnaisance, preliminary instrumental surveys will be made of one or more routes that are deemed advantageous. Particular attention will be paid on this survey to the location and levelling of the line of route and the topography noted for a convenient distance to the right and left, especially on hillsides and in hilly country generally. Notes will be made of modes of access to the line, the availability of water for construction, the positions of quarries, the railheads and transport facilities for distribution of materials, and storage.

Where a line changes direction, an angle or corner peg will be located and tied in to several reference objects, preferably of a permanent nature, so that it can easily be re-located for final setting out. When there is a long length of line between angle positions itremediate tying-in points are essential and should always be set. In the event of a corner position being destroyed or obliterated, it should be reset from the next angle or intermediate positions in existence on either side.

Care is necessary in entering the field notes, because errors in these are not rare. A direction may be given as north instead of south, or *vice-versa*; a bearing may have been transposed; or the chain or tape wrongly read. All instruments should be carefully and regularly adjusted as many sources of errors are due to defects of adjustment. In levelling, backsights and foresights should be nearly equal in length as possible, and should always be checked. The same remarks apply to horizontal and vertical angles, and no survey should be started until there is complete understanding between the engineer and his assistants regarding the signs and signals each will make during the survey.

Profiling and Maps (Route).

After determining by survey the relative positions, dimensions and elevations of the surface occupied by the line of route, it is necessary to prepare a map and profile from the field notes. The scales to be used depend on the exact purpose of the information, but generally the vertical scale of the profile will be ten times the horizontal scale, so as to bring into relief the configuration of the surface. Where the lines slopes laterally, two profile lines will be shewn, the centre line in full and the offset line dotted. This offset line is levelled parallel to the centre line immediately under the lowest crossarm. Clearances to ground are checked therefrom. If on a slope the superstructure is sunk into the ground an extension corresponding to this depth must be added to the tower.

Hot and Cold Templates.

Calculations having been made for the sag of the conductors, templates representing the suspended wires at the maximum and minimum conditions of temperature will be cut from celluloid or tracing linen for "spotting" positions of supports and checking clearances to ground. These templates are built to the same scale as the profile on which they will be used. A master template in metal is kept to check any variations in the celluloid pattern and from which any additional number can be cut. This template is extremely helpful in locating positions in undulating or rough country; on a flat route the standard spacing will be scaled on the profile and a template is not needed.

Foundations and Stub Setting.

Foundations are the keynote of all construction work, and one the accuracy and speed of setting depends the later phases of work. The actual foundation cuts are marked out from a wooden template; the lining and centre pegs to which reference has already been made, will later be used for aligning and centering the stub setting templates.

Whether manual labour or mechanical plant is used for excavating, it is advisable to cut a hole with the smallest practical working clearance to the foundation. Suitable mechanical excavators are costly and it is seldom found, after taking into consideration all factors, that they make any saving over the pick and shovel method.

The foundation stubs may be a single angle with steel grillage, or an angle with cleats or rods for keying into concrete, or some other form such as the Malone Anchor. The steel grillage is so arranged that it forms a secure and reliable foundation when set in a shallow bed of concrete to overcome slight unevenness in the excavation. The shape of a concrete foundation depends on the work it is to do, but for the same work various designs are used. The pyramidal concrete foundation like other forms has disadvantages, but is fairly economical in the amount of concrete used and the excavation that is necessary.

Concrete moulds or forms are costly, troublesome, and awkward things to move from one tower position to another. Wood and also steel plate forms are extensively used, but after experience with both types, the steel forms are preferred. They are less clumsy in construction, more easily handled during assembly, and the cost of upkeep is less. As many parts as possible are of uniform design and interchangeable.

The Malone Anchor, which takes its name from the inventor, is a type of concrete foundation having a long column of small diameter at the underground end of which is formed a bulb nearly spherical in shape. The process of preparation is simple. A hole about six inches in diameter is drilled at the same slope as the legs of the tower to a depth of from eight to twelve feet or so. Into this hole several sticks of dynamite are lowered and a long length of insulated wire is run to a battery or exploder. Some earth is dropped on the dynamite and lightly but firmly stamped and the charge is then exploded. After the shot the hole is cleaned out and the bulb calipered to test whether the desired diameter has been obtained. If the cavity is not large enough, a second charge is prepared in the same way, excepting that water is poured into the void to get full value of the explosion. In suitable ground, such as well compacted earth and clay, the cavity resulting from a known charge can be fairly accurately gauged and regularly repeated.

The foundations are set with the aid of a stub setting template built into a frame, consisting of structural steel angles and channels, to which the stubs are bolted. This frame is centred and lined to the pegs, mentioned earlier, and afterwards levelled. Around the lower end of the stub in the excavation pits, the concrete forms are placed in position. In the pyramidal forms the neck or column is about 9 inches to 12 inches square in section, and the pyramidal portion has removable doors through which the concrete is placed and afterwards worked into position. With Malone Anchors concrete moulds are not necessary and the concrete is therefore placed directly into the hole and well worked. A wet concrete mixture of easy workability is used.

The aggregate, consisting of sand and broken stone, with the cement for binding them together, has previously been brought to site ready for mixing. A 1 : 2 : 4 mixture is a common proportion for work of this nature, and the proportioning will be carried out in what is known as batch measures. Batches of about half a cubic yard are mixed at one time; first dry mixed by turning over two or three times, water being then added slowly until a mix of just the right consistency is obtained. The mixing of the ingredients is done by hand on a platform of boards to keep the concrete from contamination with the ground. Immediately after the concrete has been mixed, it is placed in the forms and shovelled over before ramming into place. Successive batches of concrete must be of uniform proportioning, and workability. After about twelve to forty hours, the forms may be removed to the next position. It may be of interest to mention that a drilling guide for Malone Anchor foundations is attached to the stub setting templates, thus making unnecessary the drilling tables commonly used. There are many other types of foundations to which it is not possible to refer here.

After the forms have been removed, the excavated material is returned to the hole and thoroughly rammed to ensure that the soil is well compacted. The surplus soil should not be removed as the backfilling will probably sink slightly for some time after replacing.

It has been necessary over long lengths of line to take borings to determine the nature of the subsoil in which the foundations will be placed. These borings have revealed in advance that standard foundations could not be used in a large number of bad positions for which special designs were then prepared. In several cases, these special designs have been subjected to test to demonstrate their satisfactory performance in the poor soil positions they now occupy.

The Building of Towers.

Broadly speaking there are three types of steel towers in use at the present time. They are: (1) broad base, with a base spread of from ten to say twenty feet square; (2) narrow base, of from two to nine feet square; (3) rectangular base. The last is not widely used. The methods of erection of these types do not differ materially except that small base structures may be assembled on the ground and then lifted bodily into position.

The steel sections from which the towers will later be built up are received from the mills in approximately correct lengths, and they are then passed into the fabricating shops for bending, cropping, punching, etc. The bays in which the fabricating of the parts is done are so arranged that the sections pass through the various operations in progressive order without retracing. Nearly all work is done to steel template to ensure speedy and accurate fabrication of the parts on a mass production scale. The punched and sheared sections are thoroughly inspected and checked at all stages of production, and are finally passed to the pickling and galvanising baths, after which they are once more examined before going forward to the erection crews on the job.

At the present time tower material is usually sent out "piece-small," that is, in unit parts of which there may be upwards of two hundred pieces per tower. When shipped abroad the pieces are sometimes bundled for convenience of handling and shipping. The pieces vary from two to thirty feet or so in length, and each piece is legibly marked with a reference letter or number for easy identification at all stages of the work. Field material schedules are prepared listing the number of each part and the bolts required for each type of tower.

A five per cent. surplus of bolts is sent to site to atone for field losses. Copies of these material schedules are retained by field headquarters and those responsible for the distribution of material and go far to speed up and facilitate the checking on receipt at railhead and in the field.

Several methods of erection have been tried at one time and another, but the "unit method" that is, building the tower piece by piece from the foundation upwards, is preferred. It is favoured because the plant required is a minimum and is easily transported from tower to tower along the line by the building crew. Twelve to sixteen men comprise a gang according to the weight of parts to be lifted into place. Of these, four men are sent ahead in advance of the building crew to sort out the component parts; they also loose bolt the bracings in the centre, and frame the crossarms and peak in readiness for the crew. Four topmen are usually engaged on the tower in fitting the sections together, the remaining four or eight groundmen haul up the parts to the topmen. A "Gin" pole, some tower hooks, a few handlines, and the usual blocks and falls, are all the plant needed. Spanners and bolts are carried in a large pocket in a leather apron worn by the topmen. One man to each corner is the usual disposition adopted by the men aloft, corner legs first and then bracings being hoisted to them as rapidly as they can be fitted together. The "Gin" pole is raised as each panel length is added. When the erectors become accustomed to the many parts they rarely find it necessary to refer to the erection diagrams issued to them. Bolts are inserted with the nuts inside the corner legs, but many erectors consider it makes for easier assembly if the reverse practice is adopted. When exceptionally heavy sections are used the personnel and plant must be augmented.

Earlier methods of erection included assembling the tower in a prone position and then hoisting it into position with "Gin" pole or frame by a tractor or horses. With this method there are two distinct crews, one being engaged solely on assembling the tower, and the other in erecting it. The speed of erection makes it necessary that the assembling crew is started and kept going well ahead of the hoisting crew to prevent overlapping. This method is sometimes said to be speedier than the unit method, and less costly, but the burden of expense of mechanical plant should be compared with the other requirements in studying the advantages and disadvantages of the two methods. The likelihood of accident in the hoisting method is more in evidence, and regular inspection of hoisting tackle for aging and wear is necessary for the safety of men and material.

Insulators and Joints.

Following the erection of towers the insulators are hoisted and fitted into position. Insulators are crated in assembled strings of the required number of discs, the crates being of light octagonal construction fixed tightly round the string with separators between each disc to prevent movement. The hardware components consisting of line clamps, grading rings, horns, etc. are tied together in sets and sent separately but ready for attaching to the string.

Just prior to erection the crate is removed and the hardware assembled with the string and then hung from the tower crossarm ready to receive the conductor. Conductor clamps for aluminium conductors are usually of the trunnion or floating type for suspension positions with cone type joints for tension points. Compression joints, in which an aluminium sleeve is put over the conductor ends and, under pressure from a small and portable hydraulic press is moulded round the conductor, are not so much in evidence in this country. With the several types of cone joint in use, it is necessary in nearly all of them to disturb and deform the individual wires of the conductor to lay them over the cones in the shell of the joint. That this is not seriously detrimental to the conductor and that the joints are a tried and eminently suitable method of terminating or connecting conductors is obvious from the many thousands now in sustained service.

One type of cone joint introduced commercially some time ago is novel and interesting in comparison. With this newer type the necessity of disturbing or deforming the individual wires is avoided and, instead, the cores or layers are stepped back to receive the cores thus leaving the stranded cable otherwise unaltered. Exhaustive tests appear to demonstrate that these joints have characteristics at least equal to others with already established reputation. All cone joints are filled with a moisture excluding solution which is forced into the body of the joint. Mid-span joints are of similar construction except that both halves are brought together with a union nut threaded right and left hand. In addition to those mentioned there is the conventional suspension and bolted tension clamp types. A bolted type of peculiarly interesting design in the "snail" tension clamp of which good reports are being made. Free swinging clamps for earth conductors are permanently earthed by means of a flexible copper earthing lead.

Whichever method is employed in making-off conductors to the joints or clamps, the preparation and fitting should be carried out with great care and properly supervised. An improperly prepared joint may fail in service with serious results. For terminating aluminium conductors on to copper, an aluminium-copper connector is used. This consists of a half mid-span joint suitably ended with a copper terminal and an insulating washer. An injection of a bitumastic solution into the joint prevents the ingress of moisture.

Conductors.

With the stringing of the conductors there is reached the last, but not the least, important phase in the construction work. Conductors nowadays are practically always stranded, the formation varying with the size of cable demanded. Reels or drums of sturdy construction containing a standard length of conductor, about one mile being common practice, are used to transport and protect the conductor in its journey to the job.

The method of running out conductors will depend on whether the line crosses open country, rocky regions, or is in cultivated areas. With free running space the drums may be mounted on a bogie drawn by horses or tractors unreeling the conductor as they move forward. Alternatively the drums are mounted on stationary stands and the conductor payed out and drawn on from tower to tower by the most suitable means. In a very rough section of line it may be necessary to run a pilot line "out-and-home-again" so that the actual conductor running may be done from the starting point by means of a hand or power winch. A code of signals must be agreed and understood, so that the travel of the conductor is always under control, thus minimising the risk of over-running a position or ensuring the slacking off of tension in the event of the conductor being caught in trees or any other obstruction.

To the end of the conductor a cable stocking or grip is laced, and to the eye end a flexible steel hauling line is attached. The unreeling is usually done by a power truck with underslung winch, and as the conductor passes each tower it is drawn far enough ahead to obtain sufficient slack to lift the wire into the running sheaves suspended from the crossarm on the tower. These sheaves are about ten inches in diameter, mounted on ball bearings, with wooden cheeks to prevent chafing of the conductor. A variation is a smaller and lighter two-sheave block with sheaves about six inches in diameter. These sheaves are hung at the level of the insulator clamp to which the conductor will later be transferred. If the length of section to be strung with conductors exceeds a drum length, another length is jointed to the first and stringing continues. When all the conductor is run out it is usually tensioned to the maximum working load and then sagged down until it attains an overtension in the neighbourhood of five to eight per cent. on the working load at the temperature at the time of erection. All sagging is done by tension methods because it is not ordinarily possible on long span work to sight the conductor as might be done on short span construction. From time to time a yoke has been used to pull out three conductors at one time but it has not proved to be an unqualified success.

Personnel and Procedure.

On transmission line work, it is difficult to have a clear-cut organisation: which is to say that, although certain personnel is absolutely necessary, a definite and rigid rule cannot be fixed for minor employees having regard to the varying conditions of construction. A supervising construction engineer with assistant or section engineers, cashier, cost and progress engineer, surveyors and foremen, together with skilled and rough labour, are all required for the building of a line. A Material Superintendent with field checkers to take care of the distribution of material to the erection crews is highly important.

Briefly explained, the work already referred to demands the following divisions on construction: Survey; Excavation; Material Distributing; Stub Setting and Concreting; Backfilling; Tower Building and Insulator; Conductor Running and Clamping In; Clearing up Route and Inspection.

This classification indicates the logical sequence of the work but a good deal depends on the timing of the delivery of material to site and the position of wayleaving and special locations. The ideal arrangement is that foundation material for the job is received and installed well in advance of tower deliveries and insulators to avoid overlapping or delay. Conductors will follow when a sufficiently large number of towers is erected. A schedule of progress requirements is prepared and every effort made to live up to the standards set.

Reports of progress are prepared daily by section engineers and sent to field headquarters to be gathered into a weekly total for all phases of work and then despatched to Head Office. Weekly returns are drawn up for all labour and engineering costs and expense for each section of line, thus ensuring a close active check on all expenditure and unit costs of work done.

Progress charts shew graphically in colour the state of all phases of work at any given time and include weather reports for the week. The state of affairs for construction and finance is then readily understood and immediate action can be taken against any conspicuous deficiency in either.

Plant.

Regarding the plant used and its distribution amongst the various crews it is not possible here to comment in detail. Be it sufficient to say that while an adequate supply of all necessary plant is an indespensible condition of construction work, there is sometimes a tendency to invest a larger amount of capital in this direction than is fully justified. While the omission of essential plant is a serious mistake, the burdening of a construction job with unnecessary items indicates an equally misplaced judgment of sound commonsense. To justify its purchase plant must be in continual use.

Fixed Designs and Tests.

It sometimes becomes necessary to design and test out on site foundations for special locations. This is a burden of expense that is usually fully justified and frequently leads to ultimate economy. All such special work is, however, a slow and tedious job, and is likely to lead to delay if the fullest possible information is not gathered together at an early stage of constructional investigation.

Discussion.

Mr. J. R. COWIE (Branch Hon. Secretary) who commented on the fact that the majority of the illustrations were of overhead lines abroad, said that photographs which he had seen recently of transmission lines abroad, notably in India and the Federated Malay States, indicated that the ground was such that in certain seasons of the year it was marshy, and in some cases even water-flooded. That was the case also in regard to some of the places illustrated by Mr. Maylett, and Mr. Cowie asked whether, in the construction of towers on such land, it was the practice to dig deep holes and to construct concrete rafts, each tower being floated upon such a raft.

With regard to junction couplers, the author had referred to the type in which the wire was forced between an inner and outer cone, thus ensuring good contact. The joints were filled with a weather-resisting material, probably some form of basic oil compound, and Mr. Cowie asked whether that material affected the conductivity of that particular type of joint and whether there was any deterioration in such a joint.

Mr. MAYLETT, in reply to the questions regarding foundations, said that no definite rule could be laid down, some towers were supported on rafts extending over the base of the structure, while others had been set on individual foundations, one per corner leg designed for the exact location the structure was to occupy. Others had pile foundations, if the bearing strata were too deep to be reached by other means. Marshy ground was generally a troublesome condition, but it was mainly a matter of its bearing quality that decided the question of which type of foundation to use.

As to conductor joints, nearly all joints in tension depended on a cone or cones, and after assembly a bitumastic solution was forced into the shell. The presence of this solution did not noticeably affect the conductivity of the joint, nor did it shorten the life of the metal.

The BRANCH PRESIDENT asked whether, in cases where wooden poles were used in the tropics, trouble was experienced as the result of attack by insects, or what means were adopted to avoid it. He also asked whether the wood poles were creosoted.

Mr. MAYLETT answered that wood poles were not used to any extent in tropical countries owing to the depredations of the white ant, against which there would appear to be no permanent or effective remedy. Creosoting was in use in many countries abroad, but not in the tropics where tubular steel poles or the like took the place of wood poles.

WARWICKSHIRE & SOUTH STAFFS. BRANCH.

Ⓟ The Protection of Coal Face Machinery and the Safety of the Coal Face Workers.

F. W. MAYNARD.

(*Paper read 18th February,* 1932.)

The mining of coal by mechanical means dates back a long way, in 1761 mining engineers were trying out a steam operated heavy pick, but without any notable success. The ensuing 100 years saw some 100 patents granted for coalcutting machines including such devices as the saw, catapult, battering ram, plough, rotary wheel, endless chain, and planing machine ; all were steam driven and, as may be imagined, of little use. Hydraulic power was tried but that also did not prove a success, and it was not until 1862 when a Mr. Firth of Leeds introduced the first compressed air coalcutting machine that there has been sustained progress ; compressed air held the field, until the ideal power medium was introduced in 1863, when the first electric coalcutter was put to use below ground. Electricity had its dangers, and accidents that happened have spurred manufacturer and user to get together and devise means of prevention ; the author here wishes to shew the advance in protection of man and machine and the greater reliability of the machines.

Quite within the memory of older members the coalcutter was a source of worry and apprehension, with its cast iron body, open type motors, projections of all sorts sticking out on every inch of the machine. The machines were fitted with wheels to run on rails, which principal was later abandoned for the skid plates commonly used today ; many projections have been smoothed off, the carcass made of cast steel, the gears totally enclosed, and also the motors, which have been made flame-proof, the plug has been placed in a position of greater safety and reliability. In short it will be generally agreed that it is the apparatus external to the coal face machines that today cause most trouble.

One important feature which had been neglected up to the last few years was a suitable chain guard for coalcutting machines. The chain of a coalcutter should be fenced to obviate the risk of a man being caught in the picks. There is now at least one type which can be fitted to any standard chain machine. It is claimed that this chain guard cleans out the cut and prevents churning the holings, reduces power absorbed by the machine, fences the chain in all positions, protects the picks, deflects the holings clear of the face, can be changed from right to left hand very easily. This guard covers the chain effectively even when jibbing in, and is not much hindrance when picking the chain : deflector plates are fitted to deflect the holings and any that do go under the holing are held up to the chain and are thrown out at the next time round. It is claimed that this device shews a saving of as much as 10% in power on several types of machine, as the holing is automatically cleaned out a large saving of labour is effected, the holings can be loaded on to the conveyor at once and are only handled once.

It was about 1900 when the first a.c. coalcutting machine was introduced with its now considered obsolete slipring motor and rotor starter ; in some cases, an oil-immersed starter was fitted. Soon afterwards the squirrel caged motor machine of today was introduced; square and squat, unit construction, cast or fabricated steel throughout, simple starter, safe plug, earth interlocks and, finally, remote control. Similarly gradual evolution took place

Fig. 1.—Old style Trailing Cable.

with regard to trailing cables for use on the coal face. The first trailers appear to have been simple single V.I.R. cables, the forerunner of the trailer proper being a flat twin cable. Many devices were tried, such as drawing singles into hose pipe, sewing them up in a rough leather jacket, wrapping them with tarred rope and canvas, V.I.R. cables were filled solid with jute and braided, then a bitumen sheath was laid over V.I.R. cables, spiral wire armouring and whip cord braiding were all tried. (See Figs. 1, 2 and 3.)

The first trailer as we know it today was introduced in 1911 when the St. Helens Cable Co. put the C.T.S. trailing cable on the market. The use of d.c. for coalcutting led to a concentric type of trailer, but a lot of trouble with this was caused by open sparking when the outer came into contact with the rails.

The use of three-phase a.c. brought the four-core trailer, as we know it today, and the C.M.A. specified

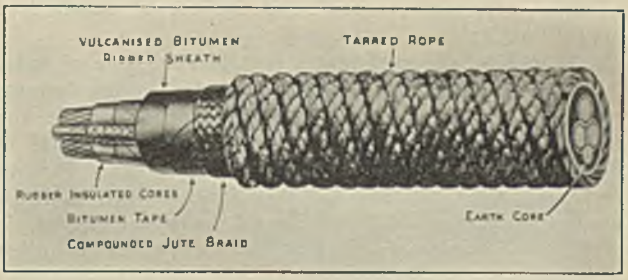

Fig. 2.—Old style Trailing Cable.

minimum size of earth conductor, 0.022 sq. in., was in line with the size mostly used for coalcutters.

Improvements of the original C.T.S. took place from time to time. The inclusion of the centre cradle, or core cushion, increased the life of the cable by about six times. Still there were accidents, some being due to strands of haulage rope coming into contact with a power core without touching the earth core and, due to this, the screened cable was evolved. It was presented in many forms, Ferflex braid, roped screens round all the conductors, and a screen round each core, all being in contact, copper and cord braided cables, and flexible armoured cables, all of which are familiar to members.

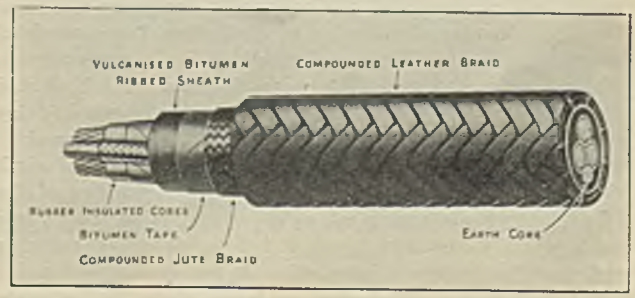

Fig. 3.—Old style Trailing Cable.

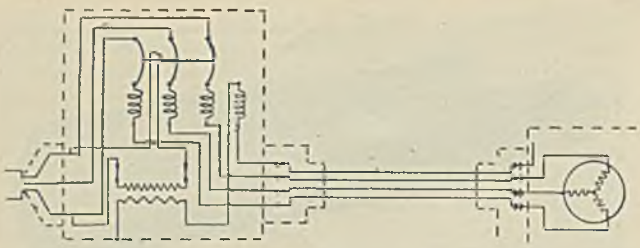

Fig. 4.—Connections of Williams-Rowley System.

Switchgear has also made strides in the right direction and has kept pace with the other items of coal face apparatus. Starting with a plain fused switch with a wooden plug or bat, and no means of earthing, then the armoured cable gland was fitted on a similar switch; with a bronze or aluminium plug with an earth pin, then a simple mechanical interlock which ensured the plug being right home and the earth pin inserted before closing the switch.

Trouble due to single phasing brought the simple gate-end circuit breaker, fitted with overload trips only, then a free handle type of breaker which could not be held in against a fault; after that came the breaker with a mechanical interlock, then the electrical interlock and earth leakage protection, the interlock ensuring that the earth circuit is correct and complete before the breaker could be closed.

Accidents still happened and the author is of the opinion that the ultimate solution of the safe use of electrical apparatus on the coal face is in the compulsory adoption of remote control, and the use of a safe type of trailing cable.

It will be admitted that a coal face machine of today is a reliable piece of machinery, as far as the internal parts are concerned, and that the protection of life and continuity of service depends on the external parts of the machine and its attendant control gear. Perhaps an examination of some of this control gear, and the various protection afforded, would be advantageous, in creating discussion in which the experiences of other members, would be pooled to the mutual advantage of all.

The switch and fuse served a very useful purpose for a long time. This type of protection is quite good for the protection of ordinary heating and lighting circuits, but if these are of any size or import then a breaker must be used.

In passing, it should be mentioned that fused gate-end boxes ought to be examined to ensure that they do not depend on the way the cable is made off, to give a flame-proof job. The author has little use for a gate-end box of that type, and will pass on to consider those of safer and better types.

A gate-end breaker having a manually operated contactor type of switch, with overload, no volt, and earth leakage protection, safe type plug and cable box, is a sound piece of apparatus for use at or near the coal face. It has its drawbacks in that should an overload occur which trips the breaker, then it is necessary to resort to the gate-end to restore the power and, should the machine be heavily loaded, this will cause delay and loss of output and temper. A gate-end breaker, working in conjunction with an automatic system of earth circuit protection overcomes most of the difficulties of the efficient control and protection of portable coal face machines. It prevents trouble due to defective earthing and, due to electrical interlocks, makes it impossible for live plugs to be withdrawn or loose plugs to be made alive. The diagram if connections (Fig. 4) explains the Williams-Rowley system. Mounted in the breaker case is a potential transformer, the secondary side of which is in series with the retaining coil, which is in series with all the contacts necessary to ensure the earth circuit being in order, if any of these contacts are not made properly, or a high resistance is present in the earth circuit, the breaker cannot be closed.

The Williams-Rowley system gives the following protective features:

Machine and trailer made dead, in the event of a broken earth circuit.

Power cut off if plug is withdrawn at either end of trailer.

Low voltage release.

Plugs are dead when withdrawn.

Power cut off if trailer is cut or damaged.

Breaker cannot be closed if plugs are not home.

Earth circuit made first and broken last.

Breaker trips on all phases and remains so till fault has been removed.

Foolproof in that the correct sequence of operations must be followed before power can be put on.

Single phasing not possible.

An earth circuit protection system, Fig. 5, developed by Messrs. Reyrolle, is based on the use of a supplementary winding on a tripping device, such as a low voltage release, which is normally energised from one phase on the live side of the switch, but the pilot is connected to a circuit in the shunted magnetic path and so only carries a low potential. The current in this circuit has the effect of reducing the magnetic leakage through the auxiliary limb to a minimum allowing the armature to be attracted in the usual way. If however the earthed pilot circuit is broken and the current in the subsidiary winding interrupted, the main magnetic flux, is allowed to pass through the auxiliary limb and the armature is released. This forms an interlock which prevents plugs being withdrawn without tripping the controlling switch, and also breaks the main circuit should the earth circuit not be intact. The auxiliary winding may be fitted to other tripping and closing coils, earth leakage transformers, etc. The advantage of this device is that no separate potential transformer is required, and no solenoid for closing. Standard switches need only slight modification to the low voltage release, and it provides an electrical interlock at a pressure not exceeding 20 volts, and 2 amps.: it may be combined with an earth leakage tripping device, the usual relay for this system being used. It has the disadvantage of other systems in that should the pilot core become earthed in its length the interlock is defeated. This fault is partly anticipated by the use of the special cable developed for the Williams-Rowley system, but in other gear it is definitely obviated by means to be explained later.

A system of earth circuit protection, Fig. 6, recently patented by the Macintosh Cable Company, overcomes the trouble of a fault occurring between pilot and earth cores. This is accomplished by providing a potential transformer at each end of the trailing cable, i.e. one in the gate-end breaker and the other in the coalcutter or conveyor motor, and auxiliary contacts are provided on the circuit breaker so that the potential transformer at the gate-end is used to allow the breaker to be closed, after which the transformer at the machine is put in circuit to supply power to the retaining coil. It is obvious that if a short occurs between pilot and earth then the supply to the retaining coil is cut off, and the breaker comes out. If simple earth circuit interlocks only are needed then this is the system to be preferred.

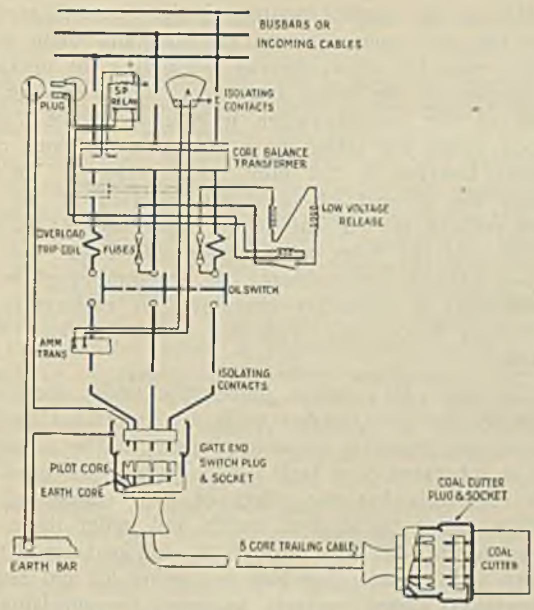

Fig. 5.—Reyrolle Earth Protective System.

From the electrical and mechanical interlocks to the remote controlled type of gate-end breaker is not a very big step, but it should consist of more than putting a coil where there was a handle, and it is extremely simple to give all the features of the earth interlocked type of breaker as well as other features which the author considers very essential for the easy and safe control of coal face machines. It must be admitted that remote control is the only system if real security is to be enjoyed whilst coalcutting or conveying are in progress.

With remote control the attendant need not handle a live trailing cable, which in itself is a great stride in the protection of life and limb at the coal face. Further, it is much more rapid in cases of emergency and as these do occur on every face, speed is most important at all times. Remote control being very simple the attendant will switch off in preference to taking any risk, which he otherwise would be tempted to do where manual control is in use.

Remote control obviates misuse of switchgear on the coal face, no making or breaking takes place at the face, and it ensures that the trailer is only alive when the machine is running. It shews saving in cost of contacts and renewals, enables conveyors to be controlled from the most suitable point, and ensures interlocks so that plugs must be right home and the earth circuit correct.

There are a number of makes of remote control gear on the market, both in the oil-immersed and air-break patterns, having various protective devices, some of which go so far as to give protection against faults occurring in the control circuit, that is, pilot wire and earth core, and also in a number of the designs the arrangement is such that individual units can be mounted together on skids to form multi-panel boards.

The Metropolitan-Vickers gear incorporates a protective device for faults between pilot and earth core. Each unit consists of a welded boiler plate tank, free of projections on the top face, and having skids at the base for mobility. The main case is divided into two compartments, the upper or smaller compartment containing the isolating switch and, when required for assembly into multi-panel boards, a set of busbars complete with interconnecting links. The ends of this upper chamber can be closed off by blanking plates or cable boxes. The lower chamber houses the following items :

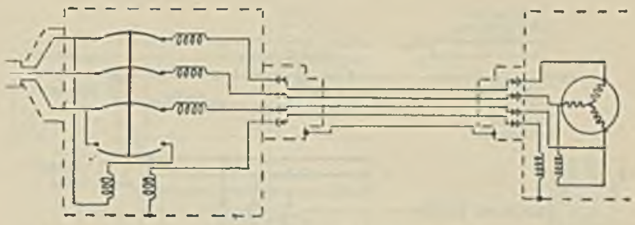

Fig. 6.—Frost-Macintosh Earth Protective System.

Triple pole main contactor with arc shields and powerful magnetic blowout for each pole, the operating coil of the main contactor being wound for full line voltage with a magnetic circuit of laminated iron construction.

Three thermal overload relays for dealing with small long-period overloads, the thermal trips having a characteristic similar to the heating curve of the motor.

Three instantaneous trip overload relays which are set slightly above the starting peak current of the motor, these relays being provided for short circuit protection between phases, or other faults.

One set of relays for the pilot control circuit.

One potential transformer with 20 v. to 24 v. secondary for the pilot control circuit.

Fuses for control circuits.

One discriminating device which operates in conjunction with a similar device mounted in the pilot control switch referred to later.

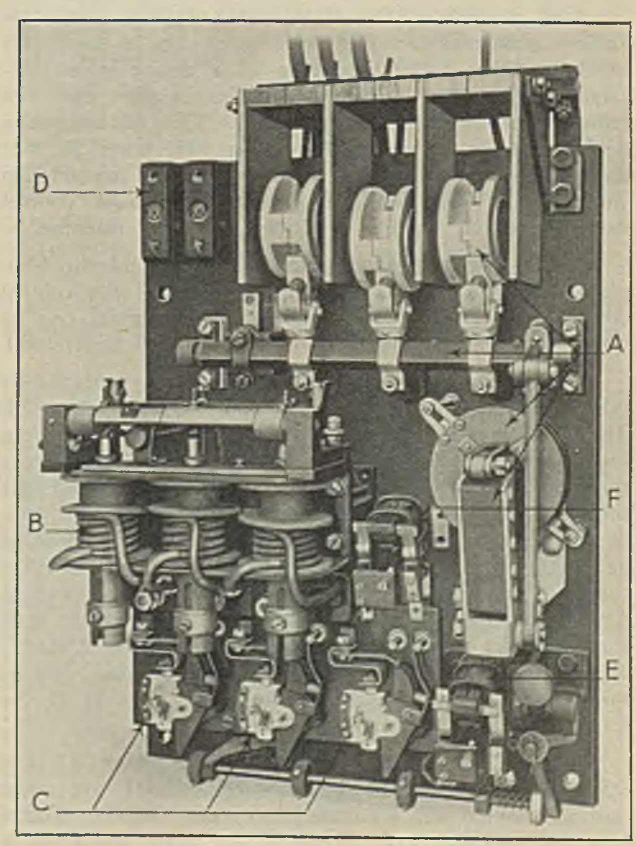

Fig. 7.—Metro-Vick Type M.U. Panel, removed from case.

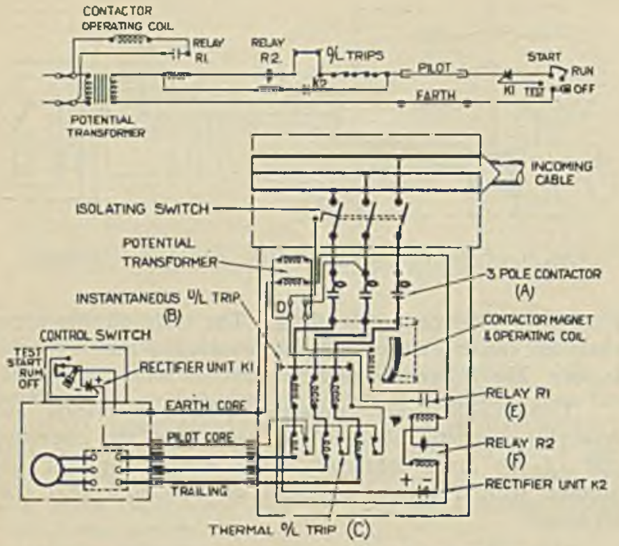

Fig. 8.—Connections of the Panel shewn in Fig. 7 : and circuits.

Figure 7 shews a panel removed from the box, and the following items will be easily recognised by the lettering and index.

A. Triple pole main contactor with renewable contacts, blowout coils and arc shields.

B. Instantaneous overload trips in three phases.

C. Thermal overload trips in three phases.

D. Fuses for coil circuits.

E. Relay R1 for pilot control circuit.

F. Relay R2 for pilot circuit protection.

In addition to the ordinary failure of voltage and overload protection, the M.-V. gear provides protection against accidental earthing of the pilot core in the length of the trailing cable by means of a device which discriminates between normal current in the pilot core and fault current in the pilot and earth. This discriminating device consists of relay R2 and a half wave rectifier unit in the main starting box working in conjunction with another half wave rectifier in the pilot control switch mounted on the coalcutter or other machine.

Fig. 8 shews a diagram of connections of the complete apparatus and a schematic diagram of the control circuits by means of which the various circuits can be traced through and the action of the rectifiers understood.

The operating coil circuit of the main contactor is taken through the contact (normally open) relay R1. The operating coil circuit of the relay R1 is fed from the low voltage secondary of the potential transformer through the normally closed contact of R2, and the thermal and instantaneous overload trips and the coil of R2 fed through a parallel circuit in series with the half wave rectifier unit K2, thence on through the pilot core of the trailing cable to the pilot control switch. At this point the circuit can be completed via the half wave rectifier unit K1 with the switch in the "start," "run," or "test" positions, and the circuit returns through the earth core to the low voltage side of the transformer.

It should be noted that when the relays R1 and R2 are not energised the contacts of R1 are open (normally open) and R2 closed (normally closed). Therefore the operating coil circuit of the main contactor is open.

Moving the control switch to the "start" position closes the pilot control circuit via pilot and earth cores, and the relay R1. closes thereby completing the operating coil circuit of the main contactor. On releasing the handle of the control switch it returns to the "run" position under the action of a strong spring and resistance is inserted in the pilot control circuit. In this position the amount of resistance inserted in the coil circuit reduces the current of the relay coil R1 to such a value that the relay will remain closed but will not re-close through the resistance on resumption of supply voltage after a temporary shut-down or replacement of the trailing cable plug with the switch in the "run" position.

The relay R2 remains inoperative under these conditions as the two rectifier units are connected back to back so that there is no current flow in the circuit of R2. In the event of a fault occurring between pilot and earth core this has the effect of short circuiting the rectifier unit in the control switch and under these conditions current will flow through the coil of relay R2 and the one rectifier unit, therefore energising R2 and causing its normally closed contacts to open, de-energising R1 and so tripping the main contactor. This is the important feature associated with the discriminating device on this class of gear, as without this feature there is a danger that short circuit between pilot and earth core will render inoperative the normal control circuit and so prevent the operator from stopping the equipment at the remote control point and permit of a withdrawal of a live plug.

It will be noted that an additional point is provided on the control switch, marked "test," which provides a means of producing an artificial fault between pilot and earth for the purpose of testing the operation of the relays. This is an optional feature provided with the object of making a daily or weekly routine test of the trailing cable.

It is to be further noted, Fig. 9, that a device is also incorporated under patents whereby the possibility of open sparking from the trailing cable, even if cut into with an axe is to all practical purposes removed, and with this trip gear a suitable trailer may have damage of any description inflicted on it without open sparking from the cable.

This last feature it will be agreed is a tremendous stride towards safer mining because it is claimed that a person cannot be killed from electric shock and the possibility of explosion due to sparking from the cable is entirely removed.

A development of remote control gear is the portable sub-station devised by Mr. W. Rea and it is a substantial addition to the available means of safe and easy control of coal face machines. The apparatus consists of any number of contactors up to six fitted inside a flame and explosion proof tank, which is mounted on wheels and having one incoming main cable box ; all other connections are by means of socket and plug, those for the motors being of the B.E.S.A. type and those for pilot cables being of two or multiple pin type, non-reversible. The pilot circuit is controlled by d.c. at 25 volts, this being supplied by a small motor generator also placed in the substation tank. The use of d.c. has distinct advantages over a.c. for the operation of contactors, voltage variation does not affect the pull on the magnet coils of the contactors, as the voltage of the generator is governed by the frequency of the a.c. supply, and providing the generator is of ample capacity, then no evil effects are felt. With d.c. magnets there is available definite current values which give novel features, which until recently were not contained in other gear.

A current of three amperes is used for closing the contactors, and a resistance fitted in the control switch, reduces this to one ampere, this being sufficient to hold in the contactor. This permits the use of a safety trip coil, so that should the pilot core come into contact with the earth core, in the trailing cable the safety trip coil operates and trips the contactor. Coupled with the fact that no relays are required, no laminated magnets, no high voltage contactor coils, no magnet heating, or chattering due to line voltage variation, coupled with the fact that reduced space is required, then the d.c. controlled a.c. contactor, has distinct advantages over the plain a.c. type ; in short, what at first may seem a complication is, when properly applied, a simplification. Another feature of this gear is the earth leakage relay, which can be set to trip at one ampere, irrespective of the proportion of the load that this represents. This trip is locked and can only be reset by duly authorised persons. Although the current required to operate this relay is so small, it is not a jewelled bearing type of instrument, the actual pivot being a ⅛ in. diameter pin.

The dimensions of a sub-station for the control of two 35 h.p. coalcutters, two 15 h.p. face conveyors, one 40 h.p. gate conveyor, and a ¾ h.p. coal drill, are 6 ft. 0 in. long 2 ft. 4 ins. wide and 2 ft. 6 ins. high including the wheels, this size is of importance where low seams are being worked and the minimum of ripping is being done in the mother gate road. It is stated that a sub-station of this type has been in use for the last three years and has given no trouble, it has not cost a penny for contacts, and only 2s. 4d. for two brushes for the M.G. set. During the whole of the period, the face was only at play for four days, with the exception of Sundays. On one occasion, due to rails being laid wrongly at the loading station, it was necessary to start and stop the whole of the conveyors for every tub, and during six hours no less than twenty-nine dozen starts and stops were made, one of the motors having a kick of 250 amps. at 550 volts. The author was rather disturbed during this gruelling treatment and examined the contacts as soon as possible afterwards, but found them undamaged. The pilot connections are by socket and plug, and the advantage of this is when moving forward, which can be done every day with ease.

This sub-station is now working on another face of 70 yards long, 4 ft. 6 ins. high and moving forward every day about 4 ft. 6 ins. It controls a road conveyor of 120 yards, a 15 h.p. conveyor, a 50 h.p. cutter and a coal drill. The control of the face and road conveyors is from the loading point by means of a three-way remote control board, so that the man loading the tubs has complete control.

It is possible to stop the face conveyors at two points on the face, at the engine and half way down the face. When a stop switch is operated a signal lamp goes out at the control point to indicate to the man in charge of the loader, who then waits for the lamp to re-light when he knows that all is clear for him to start up again. This lamp is operated at two volts, being tapped across the retaining resistance, at points giving two volts drop. By the use of this signal, all other signals or shouting are dispensed with.

The pilot switches are worth noticing, being of the pull-push type as opposed to the push button or turn knob type, or that which is incorporated in the machine starter by auxiliary contacts. The switch has three positions, off, start, and on, it being necessary to pull the knob of the switch out to start pausing at the start

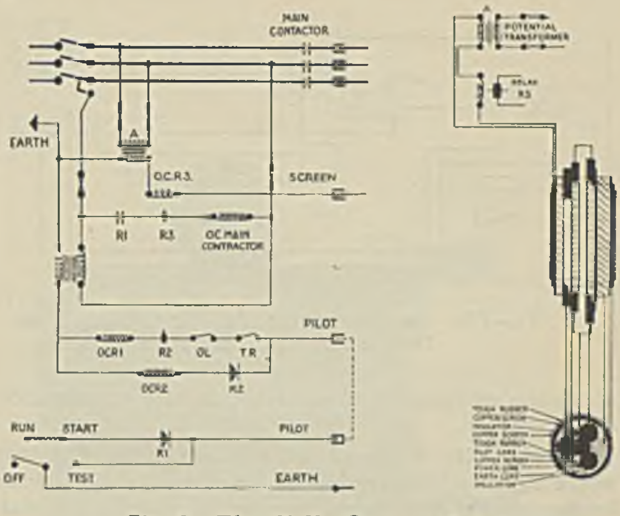

Fig. 9.—The M.-V. Gear used for Double Screened Trailers.

position for a second before pulling right out to the on position. To stop it is only necessary to knock the knob in with the hand, foot, a piece of wood, or a spanner whichever is most convenient, and the switch will withstand this treatment without complaint. When this pilot switch is fitted to an old machine, the wheel of the starter is removed, the reversing being done by means of the pick spanner ; on a new machine it is interlocked with the plug and starter in such a manner as to prevent either of these being used except in proper sequence, and under these conditions it is impossible for the attendant to break the main current at the machine.

That time is saved and also sparkwear on contacts is evidenced by the following facts. Two machines (identical with others) working on remote control have an average of 12.5 yards and 11.6 yards per hour, respectively, whilst those on manual control average only 10.6 yards and 9.2 yards per hour.

These machines are working in the same seam and the figures are of the average over a period of 12 months ; they represent a saving of over an hour a cut of 80 yards. This does not seem a great deal but if the cutters are in the way of the brushers then even a few minutes is a loss.

The averages given include flitting, turning, jibbing-in and picking the machine, and the time is included from the machine men going to and leaving the face ; further,

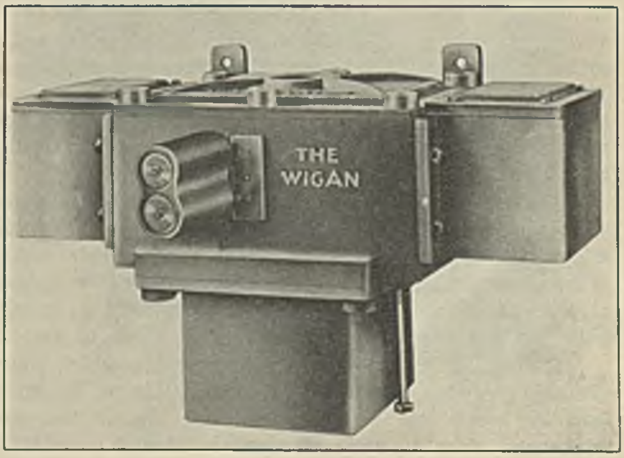

Fig. 10.—Flame-proof Circuit Breaker for small-power circuits.

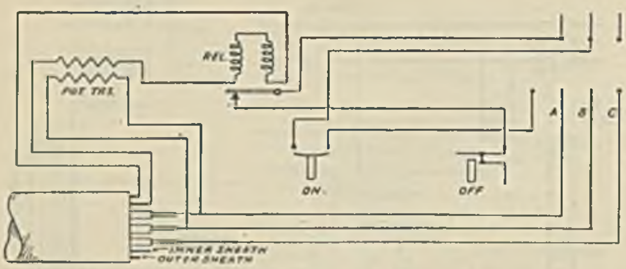

Fig. 11.—*The Breaker shewn in Fig.* 10, *used on Double Screened Trailer.*

no repairs or renewals have been necessary on contactors or controllers.

Coal drills are used extensively at the face and where electrically driven should be controlled by a circuit breaker of the flame-proof type and if possible remotely controlled. One type of breaker suitable for this purpose is shewn in the illustration, Figs. 10 and 11. This is of the electrically operated type and may be arranged very simply for remote control. The breaker has three magnetic O.L. trips and also three thermal O.L. trips and in this manner takes care of the current rush on starting and also sustained overloads by the thermal trip, whilst shorts in windings or cables are taken care of by the electro-magnetic O.L. trips. The author has used this type of breaker with every success and has several in use below ground. It can also incorporate a trip for double screened cables for use in coal face lighting or coal drills, and is certified flame and explosion proof.

A five core trailing cable is essential with this type of control gear, this should be of the earth shrouded type to give complete protection. Ferflex braided types have not been a great success owing to the braid breaking, later types are protected by a screen of roped copper conductors surrounding either the conductors as a whole or round each core, the ropings being in contact for the whole length of the cable, and connected to the earth core in the length, or at both ends. With this type of cable, and a sound earthing system it is almost an impossibility for a person to receive a fatal shock ; the author holds that the use of some such type should be made compulsory for, in his opinion, the link between the machine and the gate-end is the weak spot in most cases. The introduction of earthed shrouds does protect a man from shock, but the placing of metal nearer the surface of the sheath of the trailer increases the risk from open sparking, which may be more dangerous ; this is where the use of earth leakage protection serves an excellent purpose, for the leakage relay will operate a very small current, and the sparking, if any, is bound to be less than if plain overload protection only is used. The leakage reset should be locked, and be incapable of resetting, except by a duly authorised person, after examination, test, and if necessary, repair of the faulty apparatus.

The more complex types of trailer have been looked upon as introducing extra trouble and complication : this is probably to some extent due to the cable makers in not instructing the user as to the repairs of the cables; also to the makers of plugs in not making a suitable plug for the easy and efficient coupling up of same.

It must be borne in mind that anything which causes distortion of the components of the cable is bound to lead to breakdown at the plug, and this is the most dangerous place as the attendant is almost sure to be near the point of trouble.

(*To be Continued.*)

NEW CATALOGUES.

THE GENERAL ELECTRIC Co., Ltd., Magnet House, Kingsway, London, W.C. 2.—The catalogue X.3 covers a complete range of Air-Break Circuit Breakers including those of the "Line Contact" type. In these the usual laminated brush contacts are replaced by copper blades of larger capacity giving improved contact pressures. Other types of G.E.C. Circuit Breakers, as well as a comprehensive range of relays, are also included.

The G.E.C. Transformers catalogue is a notable publication giving very complete descriptions and illustrations shewing the detailed construction of Power Transbformers.

BRUCE PEEBLES & Co., Ltd., Edinburgh.—The Peebles Pole Mounting Transformers, which embody a number of unique features in respect of design, are described fully in this catalogue together with technical details of ratings and dimensions.

METROPOLITAN-VICKERS ELECTRICAL Co., Ltd., Trafford Park, Manchester.—The catalogue No. 7032/1 has been prepared to shew the application of a.c. Motors for the driving of Boiler Auxiliary Plant. Motors listed include totally enclosed fan-cooled motors, flame-proof machines squirrel-cage motors and double squirrel-cage motors. Emphasis is given to certain particular features of design. All the windings and rotating parts of these motors are totally-enclosed. The sealing joints are accurately machined surfaces. The motor is cooled by air forced through passages in the stator punchings by an external fan mounted on the motor shaft. These passages are arranged so that they are easily accessible for cleaning. The ball and roller bearings are contained in cartridge type housings. These specially designed housings are so arranged that the motor can be dismantled and the rotor withdrawn without exposing the bearings to dust or dirt. All squirrel cage motors are suitable for direct starting. The end windings are specially braced to resist the stresses produced in them by the current rush at the instant of switching on. Starting by switching the motor direct on to the line eliminates starting apparatus and reduces capital cost and maintenance. Squirrel cage motors can be designed to give starting torques up to twice full load torque.

BRITISH INSULATED CABLES Ltd., Prescot Lancs.—Interesting leaflets issued recently direct attention to Enamelled Wire ; B.I. Units for Feeder and Distribution Pillars ; Rockbestos Insulated Magnet Wire; "Ozone Proof" Cables ; Ebonite Sheathed Cables ; Bull-Dog Adhesive Tape.

ENGLISH ELECTRIC Co., Ltd., Stafford.—Three new English Electric catalogues deal respectively with : N. 34, Monkey Switch-Fuse for Rural Distribution ; 973-A, Handle type Cartridge Fuse and its Applications ; N. 48, Flame-proof Switch Pillar.

THE RENOLD & COVENTRY CHAIN Co., Ltd., Renold Works, Didsbury, Manchester.—An attractive booklet reproduces many illustrations shewing the extensive range of industrial usages to which these power chains are commonly applied.

M. & C. SWITCHGEAR Ltd., Kelvinside Works, Kirkintilloch, Glasgow.—The pamphlet No. K 81/3 gives general particulars of a range of single break Metal-clad Oil-break Switchgear suitable for medium pressures up to 660 volts.

BRITISH ALUMINIUM Co., Ltd., Adelaide House, King William Street, London, E.C. 4.—"Aluminium in Electrical Engineering" is a well produced and profusely illustrated reprint of a lecture by Mr. Edgar T. Painton, B.Sc. Particulars and general physical properties of the several more commonly used alloys of aluminium are given. Processes of working such as casting, moulding, plating, pressing, spinning and wrought working are dealt with.

International Aluminium Competition, 1931. Abstracts of entries. The record of the more distinctive notions submitted in the first open and general contest of this kind. The competition is to be renewed this year (see p. 415), perhaps an ingenious electrical entry will net the first prize—50,000 frs.—, which none was considered good enough to deserve last year.

Manufacturers' Specialities.

Combined Controllers for Mining Service.

The combined controller equipments described here are made by the Metropolitan-Vickers Electrical Co., Ltd. They are in two sizes, designed for the complete control and protection of motors taking up to 75 amps. and 125 amps. with maximum ratings of 30 h.p. and 60 h.p. respectively on three-phase circuits up to 650 volts. For certain services they can be supplied for ratings up to 100 h.p. Each combined equipment embodies a magnetically operated contactor pattern main switch or stator switch with over-current relays, a drum controller arranged as a starting and reversing switch, and an isolating switch. These units are enclosed in a single case, important savings being thus effected in the cost of connections between the separate parts.

The containing case is of welded boiler plate with a large removable cover, and is so strong as to be almost indestructible. It may be of the flame-proof pattern with wide rough-machined flanges, or it may be provided with watertight packing between the case and the cover. The flame-proof design meets the requirements of Regulations 127 and 132 of the Home Office Mining Regulations. For service underground in places where flame-proof enclosure is not essential, the watertight case is recommended on account of its great strength as compared with cases of the normal industrial type.

A typical equipment, with the cover removed, for use with a slipring motor and separate resistances is shewn in Fig. 1. This has a six-notch reversing drum controller for connection to an external resistance (not shewn) in the rotor circuit of the motor. Below it is the contactor type stator switch, with over-current relays and an externally operated isolator at the bottom of the case.

An alternative, shewn in Fig. 2, embodies a liquid controller for the rotor circuit, mechanically coupled to the gate-changing operating lever of the drum controller. This combination can be supplied for ratings up to 100 h.p. on 650 volt three-phase circuits.

Equipments for squirrel-cage motors can be supplied, arranged for either star-delta or auto-transformer starting and reversing, and also for stator resistance control. The auto-transformer when included is mounted in a flame-proof (or watertight) housing on the back of the controller, as indicated in Fig. 3, where the housing is removed to shew the transformer. Interconnections between the transformer and controller are made before despatch.

Control equipments are supplied for either shunt-, series-, or compound-wound d.c. motors; these are generally similar to the slipring motor equipments.

The contactor is of the three-pole pattern on a.c. and two-pole on d.c. equipments, so that when the contactor is open the motor is completely isolated. The contacts are of the rolling butt type, which open and close with a sliding action that renders them self-cleaning. The inherent quick make and break action of the contactors, and the powerful magnetic blow-outs and arc-chutes fitted to them together eliminate serious burning of the contacts even on severe starting and inching services.

Over-current protection on all lines is provided by over-current relays (seen below the contactor in Fig. 1).

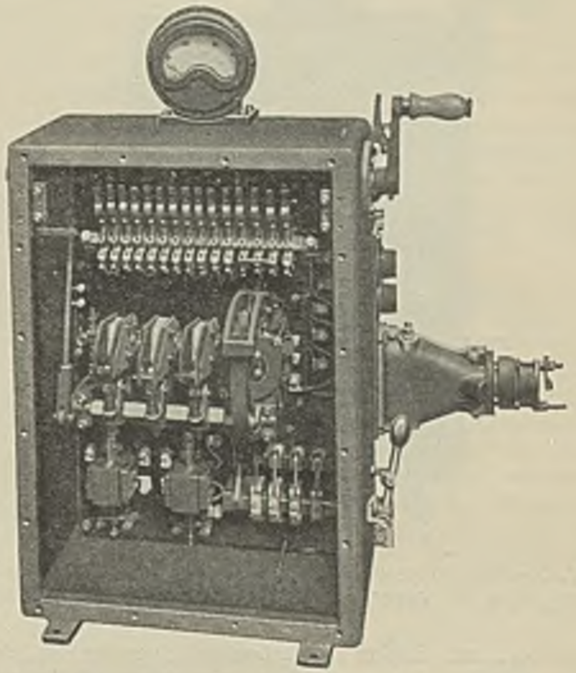

Fig. 1.—A typical Combined Controller Equipment in flame-proof case (with cover removed) for a slipring motor. The cover has been removed from the isolator.

Under-voltage release is inherent, the contactor opening automatically when the supply voltage falls below a set value. No-volt no-close protection is also afforded by the

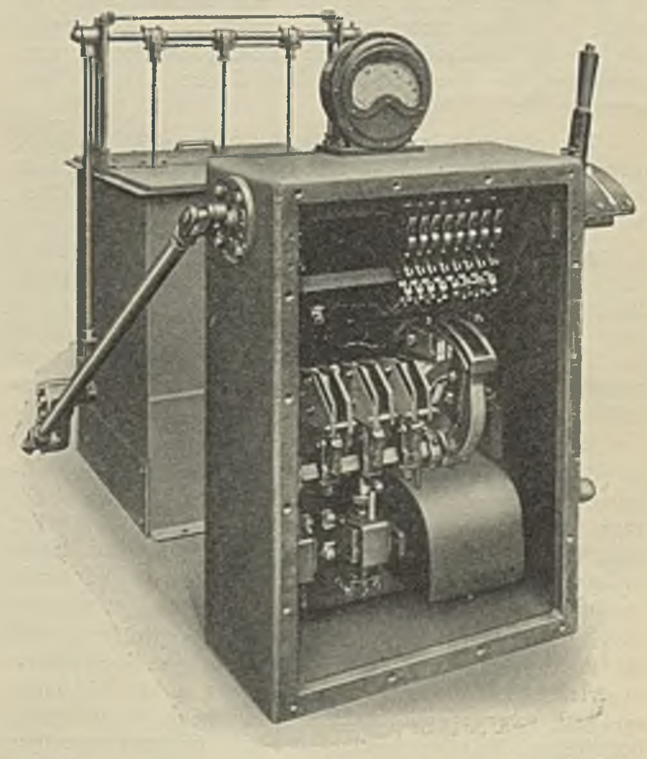

Fig. 2.—A flame-proof Combined Controller (cover removed), with lever operating gear, mechanically coupled to Liquid Controller.

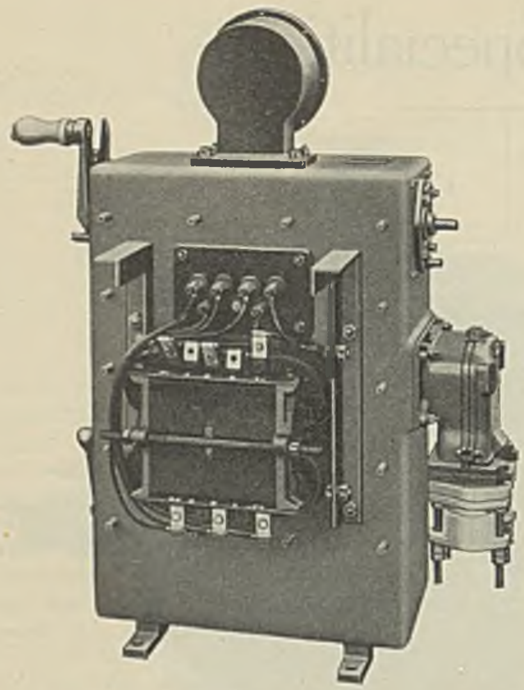

Fig. 3.—Rear view of an Auto-transformer Starter equipment with the cover removed to shew the transformer.

contactor, and further protection is given by an electrical interlock that necessitates the return of the controller to the 'start' position before the contactor can be reclosed after an interruption in the supply.

The drum controller is of the makers' standard design and construction, as supplied in large numbers for crane and steelworks service. The drum and the isolator are interlocked with the contactor, electrically in the smaller size, and both electrically and mechanically in the larger size, so that the main circuits cannot be made or broken except on the contactor. Consequently, the service required from the drum controller is very light and the drum contacts and fingers have a long working life.

The operating handle is usually of the crank pattern, with a catch for locking it in the 'off' position, as shewn in Figs. 1 and 3; but a lever type handle can be fitted as shewn in Fig. 2.

A cover shewn on the right of the over-current relays in Fig. 2 encloses the isolating switch and line terminals, to prevent accidental contact when the main case is open. The operating handle of the isolator is arranged so that it can be padlocked in the open position. An ammeter can be fitted if required, as shewn in the illustrations.

Separately mounted resistances for motor starting or speed control can be supplied, of either enclosed-ventilated, drip-proof, or flame-proof pattern. Alternatively they can be supplied mounted in an enclosed-ventilated box attached to the back of the controller, the latter arrangement allowing substantial savings to be made in the cost of interconnections.

A valuable feature of the combined controller is that all the apparatus is of the air-break type. Extensive experience has proved that on circuits up to 650 volts, oil-break gear is not necessarily superior to air-break, but that on the other hand, where very frequent operation is required, even under the severe service conditions experienced in coal mining practice, skilfully designed air-break gear has undoubted advantages.

The air-break construction of the combined controller, by eliminating oil-checking and oil-changing operations, greatly reduces maintenance costs and unproductive time; while the simplified construction thereby made possible allows the various parts of the apparatus to be made more easily accessible for inspection and adjustment.

Joints for Shaker Conveyor Troughing.

It is claimed that the costs of shaker conveying are considerably reduced by means of the M. & C. Ritchie Joint, in which there are no loose parts to be lost and require replacement and practically no wear and tear: furthermore, since the joint remains tight throughout the filling shift, time lost through stoppages to tighten bolts or correct damage due to slack joints is eliminated. In many cases the cost of moving forward has been greatly reduced.

The joint is made by two stirrups, each of which carries a set-screw. When coupling the troughs together, one of the set-screws is screwed tight (the other has been left correctly adjusted), and the ends of the butt straps are made to yield a little. This initial tightening prevents backlash or chatter developing at the joints, even with troughs that have been in use for a long time.

Each set-screw has a hardened point which bites into a mild steel pad; the point therefore remains unworn. The hard points ensure that the set-screws are easy to unscrew with the spanner at the end of the shift. The grip in the pads together with the spring of the butt straps forms a perfect lock for the set-screws; they are as tight at the end of the shift as at the start. The loss caused by slack joints is therefore saved; hammering of the troughs, spoiling of bolt threads, and unnecessary shocks on the engine are cut out, and consequently maintenance cost is reduced. Every joint remaining tight makes the conveyor run quietly.

Every part is securely attached; the pad cannot escape from the stirrup, and the set-screw need never be removed. The joint is strong; the butt straps, the hydraulic riveting, the stirrups, the set-screws, in fact all parts of the joint are strong in themselves. Moreover, the load is distributed evenly between the two stirrups; the joint is therefore stronger than any joint where the load can all come on to one side.

To uncouple the joint, slacken one of the set-screws with three strokes of the ratchet spanner provided, swing

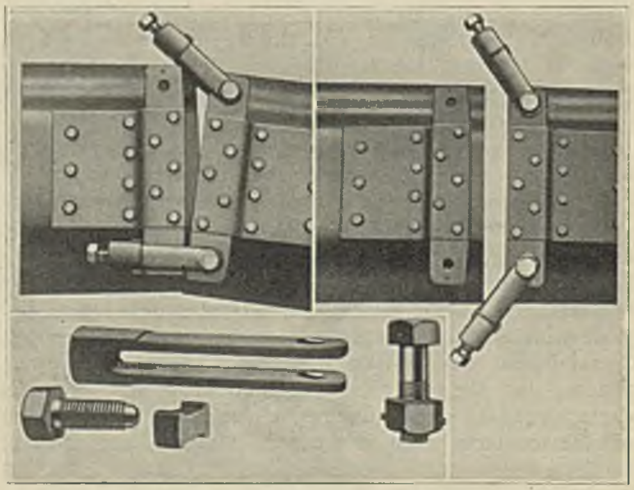

Fig. 1.—Details of the M. & C. Ritchie Joint.

the stirrup clear, and skew the trough in order to free the second stirrup. Where skewing is not convenient, the goaf side stirrup can be knocked off from the face side. Only one set-screw need be slackened ; there is therefore no need to reach across the conveyor to the goaf side. This means a great saving if the goaf is full of dirt up to the troughing, or if the roof is low, or if the packs are tight, or if a prop prevents easy access to one stirrup. The width of the joint is less than the width of the trough ; there are no projections to catch on timber while working, or to catch on low roof when moving up.

Two men have been timed moving forward a hundred yards of troughing with this joint ; including moving forward and securing the engine, they took in all two and three-quarter hours, that is one third of a shift. The cost of moving the conveyor was therefore greatly reduced.

In operation, the conveyor is extremely rigid sideways, making it suitable for side drive. Moreover, it retains this rigidity to the end of the shift, or until it is uncoupled. If required, it can even take the conveyor round a slight curve, by slackening one set-screw and tightening the other. The stirrup on the inside of the curve is then kept in place by a nail dropped into the hole at the end of the butt strap. The joint is sufficiently flexible for the conveyor to work smoothly over undulating or uneven floors. It is rigid enough, however, to prevent buckling or bridging of the troughing at such undulations, and to carry it over the driving gear for underneath drives without support at the joints next the engine. The joints are manufactured by Mavor & Coulson, Ltd., and the design, the steel, and the labour are throughout entirely British.

New Electric Winders Orders.

The Metropolitan-Vickers Electrical Co., Ltd., announce that they have recently received an order from the Harton Coal Co. for two electric winding engines to replace existing steam winders at the Boldon Colliery, the new winders are to be accommodated in extensions to the existing houses. No. 1 winder is for dealing with men only, and comprises a cylindro-conical drum having a small diameter of 10 ft. and a large diameter of 14 ft. with four turns on the scroll connecting the two cylindrical portions. The drum will be driven through single reduction double helical gearing by a 380 h.p. 2700 volt, three-phase induction motor which will be so arranged that for a preliminary period it will operate as a 16 pole machine on the existing 40 period supply and will ultimately run as a 20 pole machine on the 50 period supply which will eventually prevail.

The change-over from 40 periods to 50 periods will be effected by changing the end connections of the windings. It will be noted that the speed of the motor will be the same for either 40 period or 50 period working and the operation of the winder will therefore be entirely unaffected by the change of frequency.

The winder is required to raise or lower 15 or 20 men in each deck of the three-deck cage at the rate of say, 1500 men per hour.

The 5500 volt supply will be taken through a main switch cubicle and thence through a step-down transformer to the 2700 volt motor ; control of the latter being effected by means of oil-immersed reversing contactors and a moving electrode type controller. Complete protection against overspeed, overwind, etc., will be given by a Lilly overwinder.

The mechanical portion of the winder will be manufactured by Robey & Co., Ltd., and will include compressed air operated brakes. The brakes will normally be operated from the main colliery air supply, but an auxiliary motor driven compressor will be supplied, arrangements being made for starting up this auxiliary compressor automatically in the event of the pressure in the main air supply falling below a predetermined limit.

No. 2 winder is for raising coal and is to have two parallel drums 16 ft. diameter connected by means of a toothed clutch in order to facilitate the adjustment of rope length after recapelling etc. The drums will be driven through single reduction double helical gearing by a direct current motor of 1860 h.p. running at 400 r.p.m.

The winder motor will be supplied with current by a 1200 k.w. 600 r.p.m. motor generator set, the motor of which will be of the salient pole synchronous type rated at 1200 h.p. and having a pull-out torque of 4200 h.p., this unusually high peak h.p. being necessary by reason of the somewhat unusual decking arrangements. The synchronous motor will also be arranged for dual frequency operation, being arranged to run in the first place as an 8 pole machine on the existing 40 period supply, and eventually as a 10 pole machine on the 50 period supply. The changeover will be effected by changing the end connections of the stator windings and replacing the 8 pole rotor by a 10 pole rotor. The motor will be arranged to run at a leading power factor of 0.9 so that a certain amount of power factor correction will be obtained.

The mechanical portion of this winder will be constructed by Fullerton Hodgart & Barclay Ltd. and will comprise oil-operated brakes with small motor-driven pumps and a weight loaded accumulator. The arrangement of the brakes will be such as to facilitate the installation of a Metropolitan-Vickers brake governor at some future date.

Control of the winder will be on the Ward-Leonard system and, in addition to the usual cam gear driven from the depth indicator and coupled to the controller, complete protection will be given to the winder by a Lilly overwinder.

The winder will be required to handle a nett load of 11,200 lbs. in four decks at a maximum winding speed of 38 ft. per second, giving an output of 250 tons per hour, 50 seconds being allowed for the wind and 22 seconds for decking. As a preliminary duty, however, the decking time will be 52 seconds so that an output of only 175 tons per hour will be obtained. Both winders will operate from a depth of 1560 ft.

International Aluminium Competition, 1932.

The Rules governing this year's International Competition for the development of the uses of Aluminium and its Alloys can now be obtained from the Aluminium Propaganda Bureau, 23 bis Rue de Balzac, Paris, or from The British Aluminium Co., Ltd., Adelaide House, King William Street, London, E.C.4. The Rules are as follows:

1.—*Object of Competition.* A competition open to persons of any nationality will be held by the International Aluminium Bureau with the object of encouraging the development of the Aluminium Industry. Prizes are offered for the best suggestions dealing with the construction of new apparatus, or with improved applications of the metal or its alloys, or with improvements in manipulation, with the object of developing the uses of these metals. The International Aluminium Bureau being a department of the Alliance Aluminium Cie., whose head office is at Basel, Switzerland, Aeschengraben 22, competitors agree to accept domicile at Basel, for the purpose of the competition.

2.—The suggestions submitted for this competition must deal with the manufacture of an article, a machine, or part of a machine, in Aluminium or one of its alloys, or with an improvement in the working or use of the metal (welding, insulation, surface finish, etc.).

3.—Entries should be submitted in either English, French, or German.

4.—The proposals submitted must be sufficiently complete to allow the value of the suggestions to be fully appreciated.

They should contain a detailed description (or model if so desired) of the article, with drawings, dimensions, weight, etc., or of the process, and should give sufficient data to admit of experimental trials to enable the claims to be verified. An economic study indicating the approximate tonnage of Aluminium likely to be employed under present economic conditions, due to the suggestion submitted, should be included.

5.—The Adjudicating Committee will be composed of five engineers one each being nominated by each Company associated with the Alliance Aluminium Cie., and, in addition, one member nominated by the Director of the International Aluminium Bureau, making in all six members. The committee will regulate their own procedure in regard to meetings, methods of work, etc. In the event of an equal distribution of votes, the representative of the International Aluminium Bureau will have a casting vote.

6.—The decision of the committee on the award of prizes will be final.

7.—Prizes totalling 20,000 Swiss Francs will be divided by the committee in the month of December 1932 among the authors of the best proposals. The decision of the committee regarding the division of prizes will be final, with the condition that:

(1) At least three prizes will be awarded;

(2) No prize will be less than 2000 Swiss Francs.

8.—The opening date of the competition will be the 1st July, 1932. Entries must be submitted between that date and the 1st October, 1932 (date of posting), after which date no entry can be accepted.

All entries must be in typewritten form and must be signed by their author. They should be accompanied by a summary of not more than 300 words in which the author states briefly the object and advantages of the new invention and the new outlet which it offers for Aluminium and its alloys. Duplicate copies with full name, address and nationality of the author attached, must be forwarded by registered mail to the International Aluminium Bureau, 23 bis Rue de Balzac, Paris (8e), France. No responsibility will be accepted for documents lost in transit.

On receipt by the Bureau, all documents will be given a serial number which will be marked on the original MSS and entered in a suitable register kept constantly up to date.

One of the duplicate copies will be retained by the Bureau and the second copy will be sent to an engineer of one of the companies constituting the Alliance Aluminium Cie. (if possible, of the same nationality as the author), who will examine the proposals and report to the committee. The committee will have the sole right to appoint the engineer or engineers who, for each country, will make these reports, and may, if circumstances demand, modify their appointments. If a competitor does not belong to one of the countries represented in the Alliance Aluminium Cie., i.e., British, Canadian, French, German, or Swiss, the report will be made by a person to be chosen by the Bureau.

To facilitate the task of the committee, should the number of entries be great, the Bureau reserves the right of eliminating those which are obviously not of sufficient merit.

The entries will be examined by the committee without delay and the results announced on or before 15 December, 1932.

9.—Up to the last date for submitting entries (i.e., 1st October, 1932), competitors have the right to withdraw or alter their entries. After this date and before the announcement of the awards, all authors shall have the right to withdraw but not alter their entries.

10.—No invention for which a Patent has been granted before January 1st, 1931 is eligible for an award.

11.—In order to protect their ideas, competitors may apply for letters Patent covering their inventions. The Bureau on its part undertakes not to divulge publicly the contents of the MSS submitted for the competition which have not received an award, without due authorisation by the author so long as they remain in the possession of the Bureau.

12.—The act of submitting a proposal to the Bureau for the purpose of this competition is to be regarded as constituting an offer of the invention for sale, in the first instance to the Alliance Aluminium Cie., and then to any of the associated Companies on terms and conditions to be mutually agreed.

This option to purchase is granted in the first instance to the Alliance Aluminium Cie., and failing exercise by that Company, the option passes to the associated Companies, individually. When a number of Companies desire the right of option simultaneously the order of priority will be decided by the committee of the Alliance Aluminium Cie.

In the event of the Alliance Aluminium Cie. or its associated Companies refusing the offer, or being unable to agree on terms for acquisition of the invention, the author will resume his rights whether or not a patent has been taken out.

The Alliance Aluminium Cie., or its associated Companies, must intimate their intention of exercising the right thus reserved to them within three months from the announcement of awards or of the taking out of a patent. If no such intimation is made before the 15th March, 1933 the author resumes all rights in his invention.

13.—Entries which do not receive an award will be returned to their authors by registered post, but the Bureau accepts no responsibility if they are lost in transit. Entries may be re-entered for any subsequent competition which the Bureau may decide to hold.

14.—In submitting a proposal to the International Aluminium Bureau, 23 bis Rue de Balzac, Paris (8e), France, for the purpose of this competition an inventor agrees to accept all the rules and regulations as herein set forth.

15.—Employees of Companies associated with the Alliance Aluminium Cie., may only take part in this competition with the consent of their employers.

16.—These rules have been drawn up in English, French and German. In the event of any difficulties arising in interpretation, the French text shall be accepted.

Large Power Plant Contracts.

An important order has recently been placed with The English Electric Company by the Galloway Water Power Company through their Consulting Engineers, Messrs. Merz & McLellan, which comprises five large water turbine alternator sets and three auxiliary sets for the Tongland and Glenlee Power Stations, together with a considerable quantity of switchgear and transformers. The water turbines, which will be constructed at the Company's Rugby Works, form the largest order for this class of product so far undertaken in that factory. The generators and other material will be made at the Stafford Works.

Other recent orders secured by the English Electric Company for power station plant include a 7500 k.w. turbo-alternator set, a repeat order for a 3750 k.w. set, and a 900 k.w. pass-out turbo-alternator, all for industrial concerns in the South of England; in each case condensing plant is being supplied.

The total value of the above-mentioned contracts approximates to £350,000.