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H.M. Electrical Inspector's Report for 1930.

Better late than never will doubtless be the greeting with which many mining electrical men will welcome the new edition of H.M. Electrical Inspector of Mines Report, being that for the year before last. Furthermore, those who might have anticipated that the long preparation promised something extra in size will be surprised to find that the official scribe has in this instance found a meagre thirty pages adequate for the expression of authority. The recipient may be surprised but he will be neither disappointed nor displeased—for this latest report is a model of concentration.

The outstanding development of the Electrical Department introduced during the year was to supplement the inspectorate by appointing a deputy electrical inspector and three junior electrical inspectors to assist Mr. J. A. B. Horsley who, for so many years alone and with conspicuous success had shouldered the electrical work of the Mines Department throughout the Kingdom.

Very important too was the decision to institute a departmental section for the testing and certification of flame-proof enclosures for mining electrical equipment. Manufacturers should note that the report indicates definitely that this official work will not be confined to technical flame-proof testing but that all apparatus submitted for certification will also be critically examined in regard to design, and presumably general qualities of construction, to ensure as far as possible that there is an ample margin of safety, and that the certificated flame-proof gear shall not readily become unsafe under working conditions. This official intimation will undoubtedly, be generally pleasing to mines' engineers enabling them to purchase certificated flame-proof apparatus with a much greater degree of confidence. The manufacturers will probably view this development with mixed feelings: opinions must inevitably differ as to what constitutes ample margins of safety and permanence of safety in continued hard usage, especially so when the costs of production and selling prices of the articles are essential ruling factors.

The acceptance of responsibility regarding the effective safe performance of the certificated gear is also an important implied contingency. There would appear no reason for doubt or anxiety that the inspectorate, the mines' engineer and the manufacturer will not harmoniously blend their opinions and practices: but, whilst it is a very definite thing for a body to certify that a particular sample of apparatus has withstood certain specified physical limiting tests, it is very different to assume responsibility in criticising general design in regard to the indefinite qualities mentioned, and their survival in the hazards of the mine.

Having these particular considerations in mind it is doubly interesting to learn the cause of two serious accidents reviewed in the report. In one case a firedamp explosion killed two men and injured two others. The "flame-proof" switch box of a coalcutter had been "adapted," the switch operating spindle had been removed and the open hole remained: another hole had been cut to allow the switch-rod to be extended: thus there were two deliberately opened up large holes into the flame-proof chambers. Similarly in the other case: the coalcutter switch, dual control pattern, had the operating extension rod and hand-wheel removed—and the hole left open: there was another open hole of an inch diameter: the plug interlock was missing. It is rather impossible to attempt cool comment in face of such facts. The obvious indication is that official tests, design approvals and certification are utterly useless if flame-proof electrical gear is to be "monkeyed" with in the pit. Tragic discovery brought these two cases to light: how many similar are still hidden awaiting only the coincidence of the flash in gas ? What class of man was the electrician in charge ? These are but two of the leading questions which the conscientious mining electrical man will ask himself, and answer by considering carefully the conditions of his own place and plant.

There were during the year only eight electrical accidents underground, including the two just mentioned. There were six deaths, underground, directly due to electric shock; this was the lowest figure since 1926, though the aggregate of electric motor power in use had in the meantime increased by more that ten per cent. The risks arising from trailing cables and plugs are still prominent. Four deaths and seventeen other serious accidents were alone directly attributed to trailer and plug defects. In one case described, during the repair of a gate-end loader a sheet iron chain guard was dropped upon and cut into a live, unarmoured trailing cable. A man touching the guard was killed. There is no excuse whatever for using unarmoured trailers for work of that kind: nor is there any excuse for the carelessness of leaving current switched on the trailer: above all, what can one think about the whole sorry state of affairs when one reads that the same trailer on inspection after the fatality was found to have five other incisions exposing the cores ?

The price of this report is sixpence: it is within the reach of every miner and not only electricians and engineers but every man who works in or about an electrically equipped pit should have his own copy. We would suggest that he inscribe in bold characters across the blue front cover " Vigilance in Maintenance."

The Convention Programme.

Members of the Association of Mining Electrical Engineers will scan with satisfaction the remarkably attractive Convention Programme which their colleagues of the West of Scotland have been able to arrange. It would appear plain that so overwhelming has been the generous interest kindled in Scottish mining and electrical circles that the organisers have been hard put to it to piece together so much rich entertainment in so little time. As it is, the Convention will this year practically absorb a full week—and a strenuous one. Members and friends, from the kingdom over, are to assemble in Glasgow on the evening of Monday, June 20th. Thereafter until the following Saturday it will be a case of succeeding days over the hills and far away under the summer sun (may the weather be never so propititious) and festive foregatherings, as they say in those parts, to enliven the evenings. There are, of course, business items interspersed and they must be attended to, but even they can present no drab aspect in such circumstances.

The Annual General Meeting of the Association has for many years now enjoyed the warmth of enthusiastic members gratified with still another year's successful endeavour. The value and prestige of the Association, building firmly, is surely reflected in the practical and generous recognition so profusely accorded to it by leaders of civic, social and industrial concerns. The Convention is this year to be honoured with a Civic Reception and Dance by the Corporation of Glasgow. Places of old historic and others of ultra modern interest are thrown open for these guests.

To visit the workshops of the manufacturers of mining electrical plant, and to see the great civil-electrical achievements of hydro-electrical, or " white-coal," power generation is vastly instructive and rare information is thus acquired under enjoyable conditions.

We would, in particular, urge mines owners and managers to consider this last point, and to make the way easy for the men of their mining electrical staff to attend the Convention. When men, and especially the younger ones, are closely confined year after year to the limited environment of the usual mining town, they cannot be so capable, wide-awake, and broad-minded as they should be and as every progressive and conscientious man would seek to be: in effect, they are not so useful, not nearly the hundred-per-cent. efficiency item in specialised labour, which the man strives to be and which his employer must needs have. The days are long past when the employer shuddered at the thought of his workers knowing too much: the very opposite is to-day an axiom of competitive success. The business which is staffed by the ablest workers, from manager downwards, is bound to make progress—its wages' rates go up but the return is proportionately much greater. There are many notable examples now of remarkably successful firms who pay the highest " direct wages "—and who pay " indirect wages " deliberately and freely for the continuous education and right living which ensures that the men are the best. That is a provedly sound new principle of modern business.

Attendance at the A.M.E.E. Convention is a holiday, and more. The time and money used are so well and profitably spent that the value gained is greatly above any usual proportionate return—it is, in fact, of a nature and extent only obtainable on an occasion of this kind. We would like to see, during the convention week in June, a record muster of mining electrical men who are not " accustomed to that kind of thing." Any twinge of regret they may feel on returning to work would only be that they had for so long and in the years past missed these splendid annual opportunities.

It is necessary to emphasise the importance of getting immediately into touch with Mr. W. G. Gibb the Organising Secretary of the Convention. There is, as everyone must know, an immense amount of detail work involved in planning these affairs: the great and generous efforts of the organising committee can be best acknowledged and assisted by prompt applications from the members who propose to attend.

The Convention Programme is published on Advertisement Pages viii. *and* x. *of this issue.*

PERSONAL.

B.T.H. APPOINTMENTS.

Mr. J. W. Leach, M.I.E.E., has been appointed Manager of the British Thomson-Houston Company's London Office in succession to the late Mr. A. H. Walton, with whom he worked in close association for a number of years. Mr. Leach, besides being well known in engineering circles in this country, is keenly interested in all developments in connection with electric traction. He entered the service of the B.T.H. Company at Rugby in 1904 and since 1920 has assisted the late Mr. Walton as Sales Engineer on the London Office Staff.

Mr. E. Sayers has been appointed Sales Manager of the Coventry Works of the British Thomson-Houston Co., Ltd. He succeeds the late Mr. E. Garton, with whom he was associated for many years. Mr. Sayers commenced his business career with Edmundson's Electricity Corporation, entering the service of the B.T.H. Company in 1905. His association with Mr. Garton commenced at the Rugby Works in 1910, and just prior to the War he joined the Coventry organisation in connection with the Company's magneto business.

Mr. P. L. Edwards, B.Sc. (London), has been appointed Acting Manager of the Dublin and Belfast Offices of the British Thomson-Houston Co., Ltd. He succeeds the late Mr. W. F. Haldane whom he assisted during the last 9 years. Mr. Edwards served his engineering apprenticeship with Messrs. Harland & Wolff, Ltd., of Belfast, and has spent the whole of his business life in Ireland.

Proceedings of the Association of Mining Electrical Engineers.

WARWICKSHIRE & SOUTH STAFFS. BRANCH.

Colliery Cables.

W. T. ANDERSON.

This Branch met in Nuneaton on December 10th last, and Mr. W. T. Anderson gave a Lecture on "The Manufacture and Installation of Colliery Cables." He began with a resumé of the methods adopted in the construction of various cables and the conditions determining their choice. The intricacies of shaft cable installation and typical examples were illustrated by lantern slides.

Reference was also made to the difficulties previously experienced with paper insulated cables installed in deep shafts and in his description of the 22 k.v. cables feeding the workings in the Rand Mines, Mr. Anderson explained how these difficulties had been surmounted.

Mr. Anderson also gave useful advice for the laying of cables in areas subject to subsidence and also in waterlogged localities, while the practical work of erecting overhead transmission services was fully described. Trailing cables also received no little attention.

The interest taken was evident from the numerous questions put to the speaker, particularly with reference to trailers.

Mr. Winstanley assisted Mr. Anderson and was included in the vote of thanks moved by the Chairman, Mr. L. C. Gunnell.

Mr. Anderson suitably responded and paid tribute to the valuable assistance given by Mr. D. Kingsbury and Mr. R. O. Pomroy who had so effectively operated the lantern.

NORTH OF ENGLAND BRANCH.

Alternating Current Motors for Collieries.*

Discussion.

Mr. BURNS commended Mr. Robertson's paper as being of exceptional value at this present period of change-over. Though Mr. Robertson had described alternating current motors and their colliery uses with particular regard to the machines made by J. H. Holmes & Co. Ltd., he would be the first to acknowledge that other motor manufacturers' representatives present might add usefully to what he himself had said. Mr. Burns hoped the meeting would discuss the subject "Alternating Current Motors for Collieries" in its widest aspect, and not necessarily confine the discussion strictly to the points raised in the paper.

Naturally Mr. Robertson had not specifically mentioned the name of his Company; other representatives present would not wish to mention the names of their respective firms and, therefore, to avoid any misunderstanding, Mr. Burns would identify certain speakers in that connection by inviting Mr. Mann of Metropolitan-Vickers Electrical Co. Ltd., Mr. Ketton of English Electric Company Ltd., Mr. Morley of Lancashire Dynamo & Motor Company Ltd., Mr. Bailey of General Electric Company Ltd., and Mr. Forster of Crompton-Parkinson Ltd. to speak.

Mr. R. W. MANN, owing to limited time, did not propose to continue the discussion on the lines of general design, but to begin on the assumption that when one orders, say, a 10 h.p. motor from any recognised manufacturer, then one is reasonably assured of having a 10 h.p. motor delivered; he would, therefore, deal with certain unorthodox features of design from a practical point of view as supplied to the standardisation of frequencies in collieries. One must first of all be agreed upon the necessity of differentiating between a motor built for, say, a butcher's shop and a motor built for pit service. So many motor manufacturers to-day do not realise the necessity for design as applied to colliery service, as distinct from industrial service, and rest under the misapprehension that the addition of a trifurcating box, or perhaps, a flame-proof slipring cover is sufficient to turn an industrial motor into a mining type motor.

With some 30 years of his Company's intensive mining experience on application behind design, Mr. Mann wished to shew in a general way how the desire to build a mining type motor first, and an industrial motor afterwards, had led the trend of design in their products.

Firstly, the endeavour to reduce the overall height of a motor at the expense of its length to give more pit room to add to the ease of handling below ground. The main difficulty of small diameter and increased length was one of "hotspot" temperature in the centre of stator and rotor iron; i.e. the dispersal of the internal heat of the machine. The present reduction in diameter was only possible by the application of the M. V./Hoseason patent system of cooling† whereby in a simple fashion the cooling air is taken as close to the hottest point of the windings as possible. Illustration Fig. 1 shews the arrangement which consists of radial holes in the punchings close to the windings of both stator and rotor.

The question of mechanical strength is emphasised by the progressive increase in bearing sizes and shaft diameters; and, far from cutting machines to meet modern prices, the present range of motors from the smallest

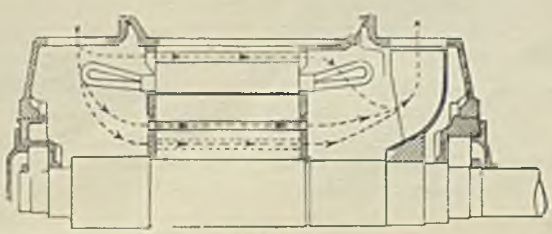


Fig. 1.

* See *The Mining Electrical Engineer*, February 1932, p. 275.

† See Hoseason's Paper before the Institute of Electrical Engineers, January, 1931.

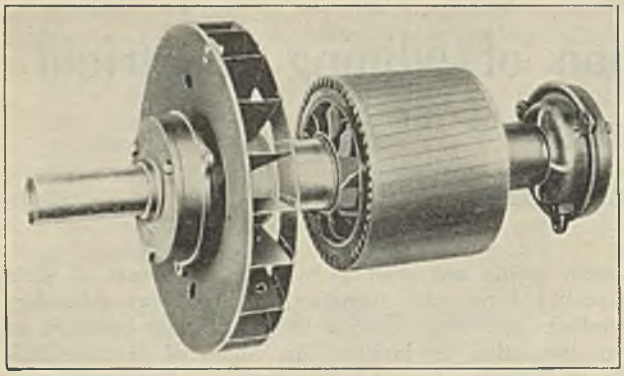


Fig. 2.

to the largest incorporates the biggest diameter of bearings and heaviest shaft that the Company had ever included for any given h.p. and speed. On smaller powers it becomes impossible to build rotors on spiders, but with such machines the method of cooling provides adequate facilities for clamping the rotor laminations together, and makes the withdrawal of an old shaft, and the insertion of a new shaft, an easy matter without possibility of the laminations falling in on to the windings.

Having mentioned the question of bearings, Mr. Mann discussed the steps taken to protect them, speaking, of course, of ball and roller bearings. The accepted arrangement is to mount these in the end bracket so that when the bracket is withdrawn the bearing is exposed. That was an excellent arrangement for the butcher's shop machine, but rather useless for pit work when maintenance had frequently to be carried out under the worst possible conditions, and certainly in a dusty atmosphere. Illustration Fig. 2 shews a system of cartridge housings whereby the bearing fit is never disturbed, and the bearings remain on the rotor shaft, totally enclosed and dust-tight, in perfect safety until the bearings are worn out. In machines of under 30 h.p. the diameter of the end bracket does not allow of this complete construction but as near as possible the same result is achieved by semi-cartridge housings.

Referring to the question of impregnation of colliery machines, the term "solid impregnation" jumped far too readily to the average designer's mind. His firm had adopted for pit service a distinct line of demarcation. It was considered that for small machines, say up to 30 h.p. spare machines could be carried which would enable a complete rewind to be carried out. Those machines were, therefore, "solid impregnated," being practically waterproof. For larger machines, when the cost necessitates the fitting of new coils in case of breakdown, "solid impregnation," or for that matter any complete impregantion was fatal to easy repair, and therefore every single coil was impregnated separately and they were enclosed in a water-tight, heat-proof sheet before winding the machine; the end windings being finally sprayed for protection against dust and damp.

On machines of approximately 30 h.p. and upwards, rotor trifurcating boxes mounted on the slipring have been dispensed with, and both stator and rotor trifurcating boxes are incorporated on the stator of the machine for easy arrangement of cables in the pit, while flameproof slipring covers are made with bayonet joints enabling the covers to be removed in a moment for inspection without the necessity of undoing bolts of any description. Illustration Fig. 3 shews such a machine where the general characteristics dealt with can be seen.

Incorporated with this range is a system of triple ratings in order to effect the maximum standardisation

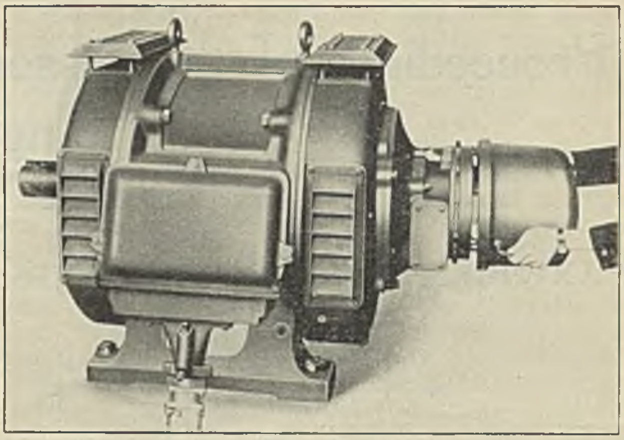


Fig. 3.

and interchangeability of machines so essential for pit use. That is to say, each frame, by an arrangement of using more or less iron in the machine, is capable of three distinct outputs at the same speed, where previously three different sizes of frames would have been used. Take for example, 75 h.p., 85 h.p., and 100 h.p. at 720 r.p.m which would be available on one frame of identical fixing centres, shaft extension, bearings, etc., so that apart from the advantage of having interchangeable spares each complete machine is interchangeable in case of breakdown.

This feature, coupled with the low height of centres, enables an M.V. machine to be fitted in the place of any other make of motor, and makes possible a reorganisation and standardisation at the time of frequency change, otherwise impossible; in one case the speaker had in mind it was found convenient to reduce 47 different frame sizes to 13, making 100% standby of motors in the pit more than a mere possibility.

The totally-enclosed fan-cooled motor was beginning to find favour amongst engineers for pit service, and the delay in their application was due, one might imagine,

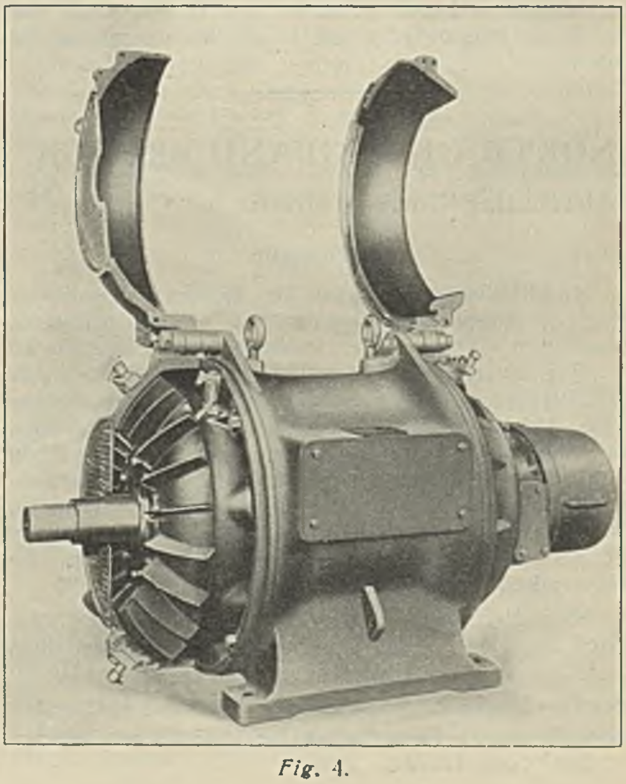


Fig. 4.

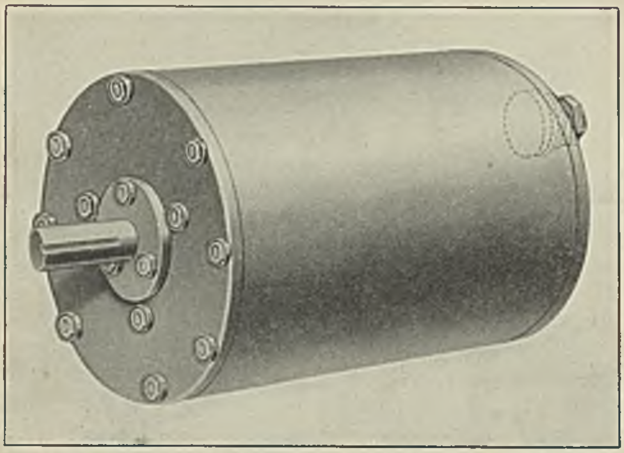


Fig. 5.—The "All-Steel" Mining Conveyor Motor.

to their original use as flame-proof conveyor motors where a motor of this type was of all, the most unsuitable owing to its turbulent effect on coal dust at the face. Here again, the requirements of colliery service had influenced the design. The principle of this type of motor is merely an orthodox totally-enclosed motor with external fan cooling. With small h.p.'s, up to say 30 h.p., the principle of a double shell with small air ducts is unsuitable for pit service where dust and dirt are likely to collect owing to the small size of the ducts, unavoidable on small machines; to meet this disability the machine was developed, in which the cooling air is directed over the shell of the machine by a strong malleable cowl so shaped that all collections of dust may be cleaned away without any dismantling whatever.

With larger machines it is possible to follow the outer duct principle, the orthodox type of which still has the disadvantage of necessitating the removal of end brackets and, in consequence, pulleys and pinions to effect the periodic cleaning esential with machines on pit service. Illustration Fig. 4 shews a development of this type where the outer air is taken through alternative ducts with the inner air crossing over at the end as a kind of heat interchanger, mechanically arranged with the outer shell end bracket hinged in halves, so that all external ducts can be cleaned without dismantling any part of the machine. Lubrication is extended through the double shell by means of a key operated Stauffer lubricator.

With regard to the latest development of flame-proof conveyor motors, the illustration Fig. 5 shews an all-steel machine of the cylindrical type made this way for two main reasons. (1) So that it may be rolled along the roadways of restricted height, and (2), so that detachable feet of various types may be fitted to make one motor of a given h.p. and speed interchangeable with a number of different makes of conveyors. This machine incorporates, in common with all squirrel cage machines of M.V. manufacture up to approximately 30 h.p., a specially constructed indestructible rotor of the solid cast type, whereby the rotor bars, end rings and fan are cast in one piece into the rotor laminations ensuring absolute freedom from loose or broken bars where heavy direct starting/reversing service is required. The particular advantage of this design is that the solid construction of the rotor enables the inside bore to be machined before pressing on the shaft, thus obviating loose rotors, and enabling an old shaft to be pressed out and a new one inserted without any difficulty in case of fracture. Illustration Fig. 6 shews a typical rotor.

The frequency change offers to all collieries an unparalleled opportunity for the re-equipment of pits on the most up-to-date lines, and the most careful consideration should be given to the choice of machine and its suitability for the arduous work it will have to do, as directly opposed to the requirements of design of a purely industrial motor.

Mr. KETTON said that Mr. Mann having dealt extensively with the smaller types of machines, he proposed to confine his remarks to the larger machines which were of special interest to members at the present time.

Mr. Robertson in his paper had mentioned that the dual frequency reconnect motor was not so suitable for this district: Mr. Ketton did not quite know what was really meant unless the reference was to the fact that it was not altogether an easy matter to build such a machine for the two frequencies that had to be taken into account in that Area. In other districts such as Glasgow and Birmingham the dual frequency reconnect motor only needed to have a number of changeover links in order to convert it from 25 cycles to 50 cycles, and the actual process of making the change was, therefore, quite simple.

When the problem was first put up of devising a suitable winding for a dual frequency reconnect 40/50 cycle motor, not the least difficult portion of the problem was to design a type of winding whereby it would be possible to reconnect the machine in the very limited amount of time available during an ordinary week end stoppage, and be able to do so with a winding that would be in every way as robust as would normally be employed in a single frequency machine. His Company succeeded in producing such a motor; they had already supplied motors for four colliery winding engines and had others in hand for driving main ventilating fans and for direct coupling to vertical air compressors, the motors ranging in power from 330 b.h.p. to 800 b.h.p. In these machines the stator and rotor windings are of the two-layer type consisting of completely formed and insulated coils giving a basket type of winding. These windings are not provided with detachable or sling links but the change in the number of poles is

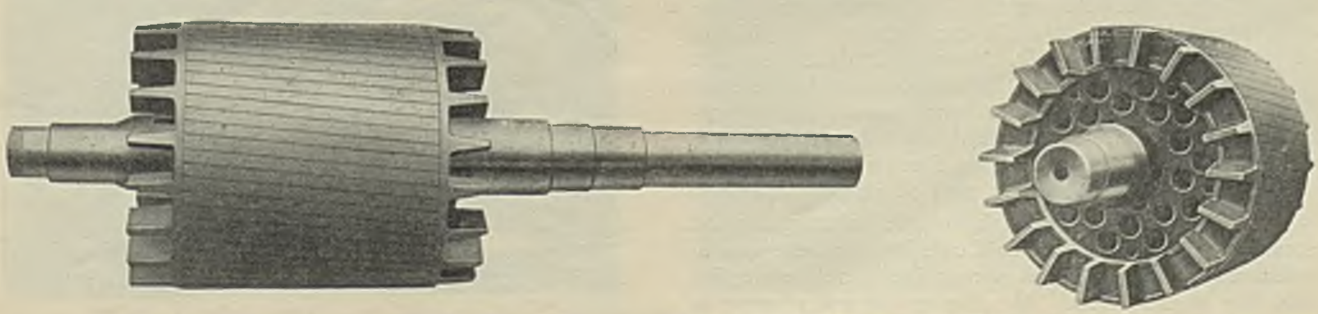


Fig. 6.—The rotor bars, end ring and fan are cast in one solid piece in the rotor laminations.

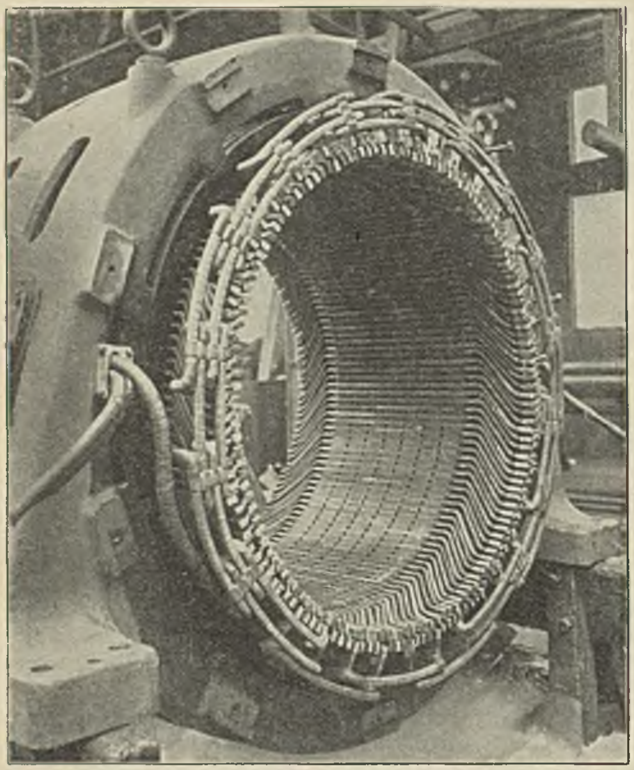


Fig. 7.

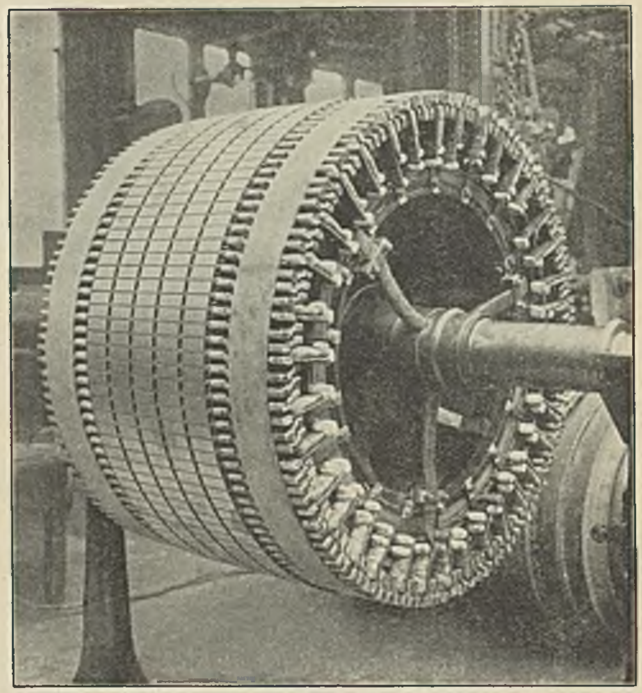


Fig. 8.

obtained by re-grouping the windings. This is done by alterations to the end connections. The windings are accurately balanced, both as to voltage and phase, on both frequencies. The machines are first of all connected up at the works for 50 cycles and are tested at that frequency; the 50 cycle end connections are then removed, properly labelled and packed in a box which is sent to site with the motor, where they remain in the packing case until required for the change-over from 40 to 50 cycles. The motor is then connected up as a 40 cycle machine and tested as such before despatch from the works.

Mr. Ketton said that the time required to reconnect the machine did not exceed about 30 to 36 hours, depending upon the number of poles and the horse-power of the motor.

In the January (1931) issue of *The Mining Electrical Engineer* there was an article describing a dual frequency reconnect electric winder required for a North East Colliery and the views illustrated herewith, Figs. 7, 8 and 9, shew the particular 625 volt three-phase motor for driving the winder in question.

Mr. Robertson had asked for information as to the maximum size of squirrel-cage motor that could now be supplied for switching direct on to the line. The English Electric Co. have offered to build motors of over 1000 h.p. for this method of starting and have actually supplied ten-pole 50 cycle motors of 585 h.p. for direct-on starting. Mr. Mann had made reference to the axial system of ventilation now used by certain firms in place of the more commonly used radial ventilation. The former method of cooling had been the standard practice of the English Electric Co. over quite a large range of machines for many years.

Mr. MORLEY said the paper by Mr. Robertson shewed clearly what could be done by the designer and the way in which new types of standard commodities could be supplied when the demand arose. Mr. Morley did not propose to deal with details of manufacture, but would like to refer to one point mentioned by Mr. Robertson in regard to squirrel-cage motors. It would interest members to learn that his firm have recently designed two 1100 h.p. 3000 volt motors for direct switching.

He noted Mr. Robertson's remarks regarding the subject of ball and roller bearings and was glad to see the author endorsed his firm's experience. There was one method Mr. Robertson did not mention for heavy drives, that was to put in two roller bearings to take the thrust on the mechanical side. Another point was the question of grease: a good many users would insist on taking the nipples off the caps and consequently every man on shift would give the lubricator a turn.

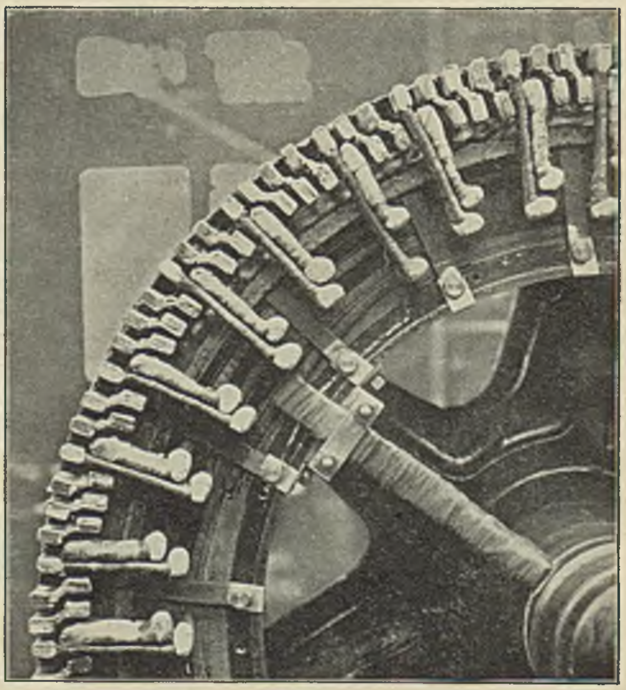


Fig. 9.

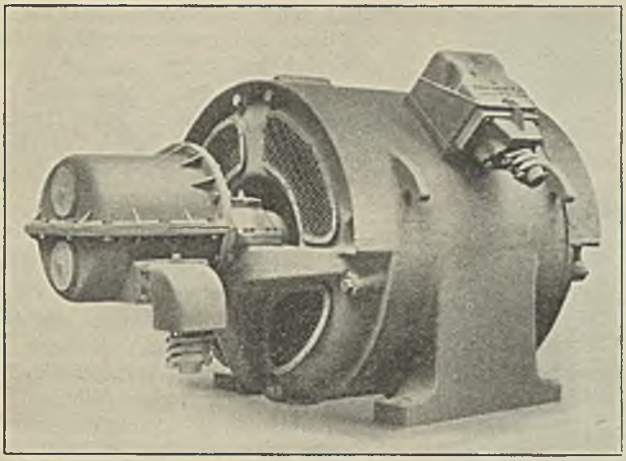


Fig. 10.

Mr. BAILEY proposed to confine his remarks mostly to one point—the vital one—the robustness of colliery motors. Electrically, he did not think it a difficult matter for any reputable firm to turn out a good colliery type machine; but mechanically, there was great variation due to the fact that there was a tendency for the makers to adapt so far as possible their industrial designs. Considering the duty called for in a Colliery Motor it followed that it was seldom a maker's industrial design would lend itself to colliery requirements. His Company—the G.E.C.—had these facts in mind when designing the motors for a large colliery contract they had in hand for that district at the present time. Although the G.E.C. had manufactured very successfully a large number of Colliery machines, they believed that these latest machines marked a distinct improvement

The illustration, Fig. 10 shews one of the 100 h.p. 465/580 r.p.m. three-phase, 2750 volt haulage motors with journal bearings. It will be noticed that the drip-proof canopy at each end of the machine is an integral part of the end bracket. A neutral terminal box is provided in addition, and the multiplate relief valves on the flame-proof slipring cover can also be seen. Eye bolts are replaced by substantial lifting lugs cast with the stator, and the general and detailed dimensions are such that ample robustness throughout is obtained.

The illustration, Fig. 11, shews a similar machine but of 50 h.p. 580/725 r.p.m. In this case the machine is fitted with ball and roller bearings.

Mr. Bailey also exhibited lantern illustrations of a flame-proof face pump motor and an outline drawing of one of three winder motors—an 875 h.p. 290 r.p.m. three-phase, 40 cycle 2750 volt dual frequency re-connect machine.

Even for surface work present day requirements call for ample protection of rotating parts at each end of the stator, heavy guards giving enclosure right to the bearing housings. This last mentioned machine and another similar motor, but of nearly 1000 h.p. covered by another contract would be one of the largest geared a.c. winder drives on the North East Coast, and the design fully complied with the Supply and other Authorities' requirements.

Mr. C. E. FORSTER.—Reference had been made to "industrial" motors not being much good for use in collieries, but it would appear that the motor illustrated by the first speaker was essentially an industrial motor, due to its big fan and system of forced ventilation where air is forced through small, or comparatively small, holes punched in both the stator and rotor laminations.

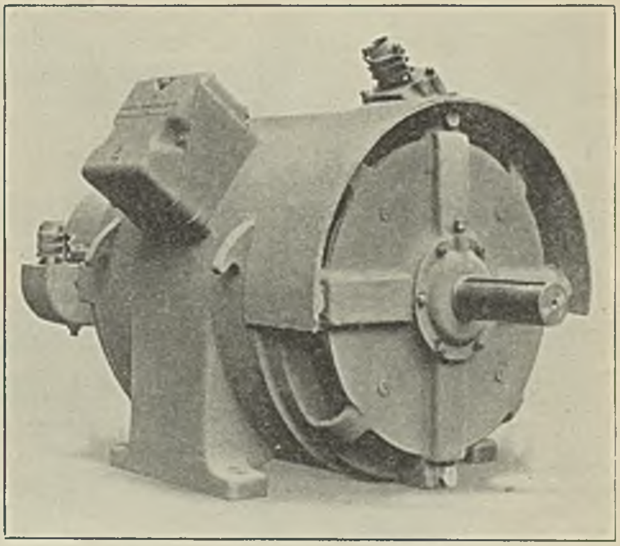


Fig. 11.

Mr. Forster would imagine that in an atmosphere charged with coal dust, the probability was that the ventilation holes would tend to become choked, particularly if the dust was moist.

Mr. Forster exhibited a slide shewing the constructional details of a modern, robust squirrel-cage motor which stands up to arduous duties exceptionally well. Fig. 12 illustrates a slipring motor driving a main and tail haulage: it is to be noted that the gear guard was specially removed for the purposes of taking this photograph: Fig. 13 is of a 200 h.p. motor driving a main and tail haulage at a shaft bottom.

Mr. Forster said it was undoubtedly true that, in the past, totally enclosed motors however desirable they may have been, proved too costly for use on many drives. With the advent of the double carcase "Klosd" motor the position had changed. In this type of machine there is quite a big space between the two carcases and none of the surrounding air comes in contact with the windings. The motor may require cleaning occasionally, and to do this, it is only necessary to remove the end

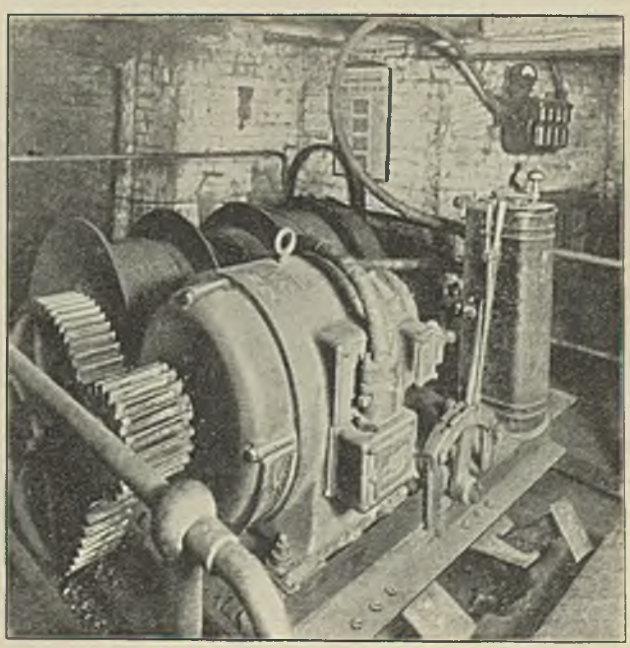


Fig. 12.

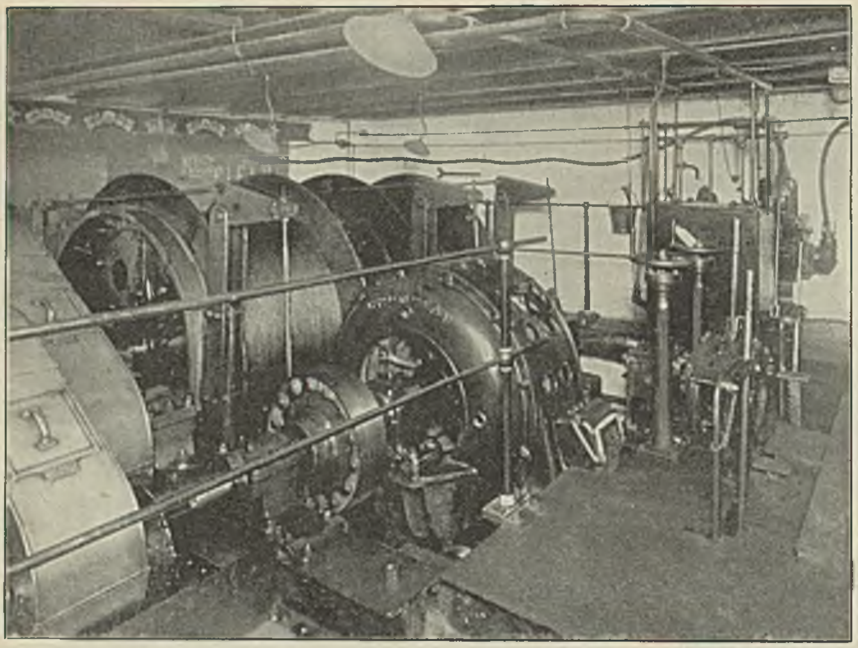


Fig. 13.

might cause a current rush of 2½ to 3 times full load current. In the motor shewn there was no such current surge, the motor slipping into synchronism at the most favourable instant. The value of this feature was obvious when driving by ropes or gearing.

The diagram of connections of this machine is shewn in the Fig. 15. Having the two-phase rotor windings with the exciter in the neutral point, it does not have to withstand abnormal voltages during the starting period. When the machine is up to speed, one phase becomes short circuited on itself and acts as a most efficient damping winding, the remaining phase carries the exciting current so that the advantages of efficient single-phase excitation is secured in conjunction with polyphase starting.

Mr. Forster then exhibited a slide shewing a Delta/Parallel/Star machine, one of several required in connection with the change of frequency at a group of collieries on the North East Coast.

Referring to various methods used for end brackets location, Mr. Forster said he was of the opinion that a spigot was by far the best method to employ where fine machining coupled with inspection during manufacture effectively prevented the tolerances being all in one direction.

In regard to insulation, he would suggest micanite to Admiralty specification (i.e. 90% pure mica) between leatheroid cells ; and, for the wire, double cotton covering reinforced with cotton tape, the whole being suitably impregnated. As to impregnation, it was generally agreed that non-vacuum impregnation had many advantages over vacuum impregnation and long experience had shewn the materials and processes adopted well able to withstand the worst conditions, including those met with in collieries and in humid tropical climates.

shrouds (not the end brackets, they and the bearings are not disturbed) clean out the space and replace the shrouds. Mr. Forster thought that a motor of this class with hinged end brackets, as shewn by Mr. Mann, would not be suitable for installation in many situations underground due to the extra head room required by nature of the hinged portion.

For power factor correction, the auto-synchronous motor was used a great deal and a motor similar to that referred to in the paper is shewn in the illustration, Fig. 14. In this particular machine the exciter is kept in circuit all the time. In some machines, the exciter is kept out of circuit during the starting period and thrown on the secondary winding by a changeover switch. There is a rush of line current to pull the motor into synchronism, the value of which depends on the relative position of the stator and rotor poles at the moment of closing the switch. This could not be controlled by the operator and, if closed at an unfavourable moment,

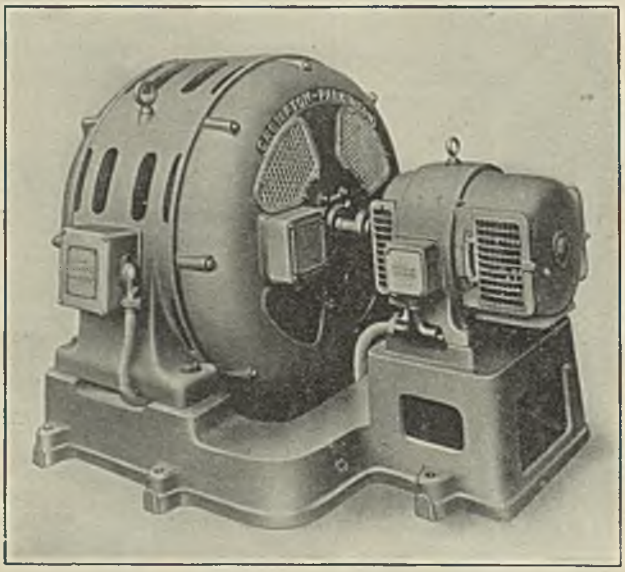


Fig. 14.

Mr. BURNS thanked the several manufacturer friends for the useful information they have tendered. He was looking forward to a further chat with Mr. Robertson in regard to the performance guarantees of 40/50 cycles interfrequency motors, particularly regarding his suggestion that compliance with the N. E. S. Co.'s " Interfrequency Specification " involved the adoption of frame sizes somewhat larger than those required for straight 40 cycles motors wound with the same number of poles. Mr. Robertson would recall that the specification stipulates for 50 cycles performance not inferior to that of a straight 50 cycles motor such as the same Manufacturer ordinarily would supply in response to a " straight 50 cycles motor " order, i.e. a 50 cycles motor built upon a smaller frame than that on which the interfrequency machine is to be accommodated and for 40 cycles performance which, as regards efficiency, may be 2 per cent. poorer and, as regards power factor, may be so much as 6 per cent. poorer than that of the straight 40 cycles motor of the manufacturer's standard type. Mr. Burns believed he could understand that the core dimensions of the interfrequency motor may be somewhat greater than those of the core of a straight 40 cycles motor, calculated on a theoretical basis, but the fact remained that interfrequency motors seldom were supplied on anything larger than the appropriate standard 40 cycles frames.

Mr. Burns was pleased the author had drawn attention to the relative power factors of 40 cycles motors and of 50 cycles motors wound with appropriately greater numbers of poles because that prompted him to enter a further plea for the careful "motoring" of drives at change-over; otherwise it might be found that the undoubted advantages arising out of Frequency Standardisation in that Area had been to some extent offset by a reduction of the system power factor.

Mr. H. W. CLOTHIER said that there were two items of practical interest upon which some doubt existed at the present time: 1, the size limit to direct starting of motors; 2, the flame-proof enclosure of motor terminal boxes. The author had made a somewhat guarded statement that direct starting was suitable for "large motors." Would it be possible for Power Companies and Users to determine some formula for fixing the sizes of motors which could be started in this way? One of the advantages to be gained from the Grid was that it gave much more power behind, so that heavy starting currents could be accommodated without undue interference with voltage in the vicinity; and, therefore, as a consequence of the Grid connections, larger motors could be direct started in the future than in the past. Seeing that modern motors were made mechanically strong in order to withstand short circuit stresses, a considerable simplification was effected by direct starting in preference to the alternative of interposing an auto-transformer in the starting circuit, or even a Star-Delta switch which could itself be a simpler device, but it had the added complications of requiring additional cable connections.

As to the flame-proof construction of motor terminal boxes, Mr. Clothier thought the author's recommendation to make the covers flame-proof required emphasising. Judging from the illustrations put on the screen by the previous speakers, the strength of the covers and the quality of the joints were not up to the standards of colliery working such as were required by the study of switchgear enclosure. Whilst he believed that regulations had not in the past called for flame-proof enclosure, he thought that the conditions within the terminal boxes including bare conductors mounted on insulators, which were liable to failure when exposed to moisture and dirt, warranted just as much attention to strength and flame-proof properties as any switchgear enclosure.

Having regard to the frequency change under which new plant was available in exchange for old, the time was particularly opportune for engineers to concern themselves with the detail construction of motors, and this should include a close inspection of designs and manufacturing processes now available.

Mr. BAXTER referred to the ventilation of motors, and could not help thinking that the ventilating system on the majority of motors was either badly designed or not designed at all. The blades of a fan were carefully curved in order to ensure an easy flow of air, but on some of the slides exhibited it seemed to him that the motor ventilating fans appeared to shew little or no improvement upon windmills. In many motors the mechanical construction of the ventilating fans was certainly defective and he knew that considerable trouble in that respect was experienced by users.

They had been shewn how the dimensions of a motor for a given horse-power had progressively decreased since 1910, but they had not been given figures shewing the corresponding changes in performance over that period.

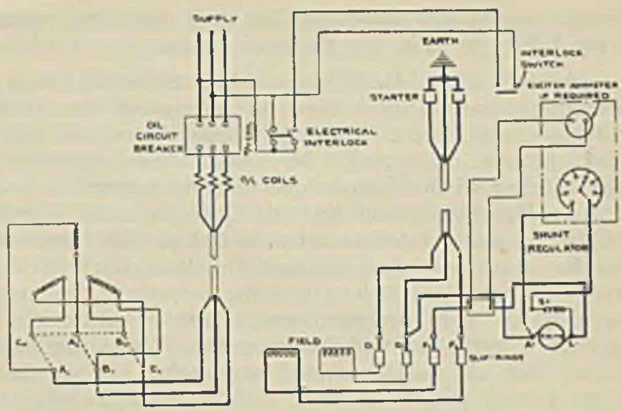


Fig. 15.

It seemed to him that the reduction in size had been effected by arranging for more rapid cooling and he believed that the windage losses in these modern motors must be heavy.

Mr. Baxter was in complete agreement with the suggestion that solid impregnation on large machines was unnecessary and inadvisable. There were members present who had installed machines to rigid specifications calling for solid impregnation and who, later on, had boasted about the wonderful repairs they had carried out underground; and, of course, the repaired parts could not have been solidly impregnated. It was an undoubted fact that a fault on a really well impregnated stator or armature generally necessitated a complete rewind.

Direct starting on many drives was a very attractive proposition but it would be found that there was some difficulty in obtaining suitable starting gear for machines of say 500 h.p. on a 440 volt circuit.

Mr. Clothier had deprecated the use of cast iron in switchgear intended for colliery use, but it was to be noted that in that district cast iron was being made in special furnaces with a tensile strength of 22 tons per square inch which, compared with ordinary cupola iron, would enable designers to make parts lighter or alternatively leave them very much stronger.

Mr. FISHER.—During the last twelve months, Mr. Fisher had visited many large works, and had been impressed with the liberal use of fabricated steel in the construction of motors, etc. Generally speaking it was only on the larger sizes that this type of construction was used. He would like to see "fabricated" construction for the smaller mining type motors; although several firms were already doing so, it was not general practice. Fabricated steel construction should, in his opinion, be used on all conveyor and coalcutter motors.

The totally-enclosed fan-cooled motor was very suitable for certain mining conditions, but as most makes of this class of motor, were provided with very thin end shields (often only a ¼ in. thick) they were too delicate for use in mining and that was where fabricated steel construction would prove beneficial.

One important point that Mr. Fisher would like to bring to the notice of all motor manufacturers was that they should pay more attention to the methods of keying, clamping, or securing the stator and rotor laminations. Mr. Fisher had recently had a large number of repairs to carry out on motors from 5 h.p. to 450 h.p. which had failed through loose stator or rotor cores. He had also noticed the great variations in shaft extension sizes. He had occasion to ask for quotations for a number of 20 h.p. and 25 h.p. motors from six different firms and found that the shaft diameters varied from $1\frac{11}{16}$ in. to $3\frac{3}{8}$ in. for the same rating.

Another thing, Mr. Fisher wished the manufacturers would provide a better class of nameplates for their machines, many were using very flimsy plates and these soon became obliterated. Mr. Mann had referred to the building of motors of three different ratings on one frame; Mr. Fisher said that his Company used a type of haulage motor rated at 25 h.p. to 60 h.p. The windings of the machines were substantially the same; if the stator is connected delta, then the motor can be used as a 60 h.p. open protected motor, and if connected in star as a totally-enclosed 25 h.p. motor. Mr. Fisher had found this class of machine very useful and he had quite a large number at work.

A good deal had been said with regard to ball and roller bearings and the use and misuse of grease in connection with them, but very little had been said about the quality of the grease ; if that was not of the right quality, trouble would result and motor manufacturers might recommend in the machine instructions the makes most suitable.

Mr. Baxter had referred to the fans fitted to motors, as had also another speaker: Mr. Fisher regretted that he could only confirm their remarks, he went so far as to consider it a disgrace that so many of these fans were so badly constructed that they quickly fell to pieces and caused serious trouble.

Mr. Clothier had remarked upon the cast iron boxes provided for stator and rotor connections. The question of making these flame-proof was, Mr. Fisher believed, under consideration: he agreed that where live terminals existed they should be in a flame-proof enclosure.

A matter which had not been commented upon was the construction of sliprings: generally speaking these were either too light or too small. Mr. Fisher was referring chiefly to motors fitted with rings for continuous running, in which there was a tendency to skimp the sliprings. A little more attention might be paid to the metal used for the rings, the best composition had been found to be Admiralty gun-metal (copper 88, tin 10, zinc 2) and if rings were annealed the wear both on brushes and rings would be greatly reduced.

Mr. J. E. LAMBERT recalled that in the old d.c. days many motors would arrive at the collieries equipped with some form of pressed sheet iron fan and generally after the motor had been in use for some time, these fans had given so much trouble that, nine times out of ten, they were taken off and the motors left to run without them. He would, therefore, suggest that Mr. Robertson might give: 1. details of the construction of these fans, including the type of blades and material; 2. say whether any of these fans had been tested to destruction; 3 say whether any motors he had in mind were only suitable for the predetermined direction of rotation when fitted with fans.

Mr. Robertson had stated that ball and roller bearings had now reached such a state of perfection that they could be relied upon to give good service even on exceptionally bad drives. Mr. Lambert would be pleased to have his views as to the limits in sizes of motors fitted with those bearing on the following applications: 1. where the drive consists of a heavy rope or belt pulley keyed direct to the motor shaft; 2. a motor coupled through a solid coupling to a jack shaft fitted with sleeve bearings and, alternatively, with a flexible coupling instead of the solid ; 3, a motor with a steel pinion of a straight cut heavy pitch keyed direct on the shaft; 4. a drive with an extra amount of end thrust, such as a worm driven aerial flight.

In regard to the arrangement of terminal boxes, would Mr. Robertson state the number of positions available for both stator and rotor trifurcating boxes; also particulars of the type of gland on the trifurcating boxes and whether any form of universal gland is available.

The term "mechanically interchangeable" was very frequently used: would Mr. Robertson care to give some idea as to the degree of accuracy which one might expect to meet on two mechanically interchangeable motors.

Mr. HEPBURN said it seemed to him that many manufacturers failed to realise that haulage motors, for instance, were subjected to strains nearly akin to rolling mill motors in steel works and called for similarly robust construction. He had in mind some seven motors of 400 h.p. which were called for ; only one manufacturer had the courage to tackle the job and, reluctantly, manufacture a motor according to the requirements. Not one of those motors has given a moment's trouble during about 20 years. The breakdowns which occurred were not due to defects in manufacture but to circumstances over which the manufacturer and user had no control.

In all the cases described at the meeting there did not appear to be one in which the coupling was forged solid with the rotor shaft and that point of construction for heavy machines was worthy of consideration. Mr. Hepburn was glad to learn that rotor shafts were being made heavier than originally which was all to the general good because many machines lacked mechanical stiffness.

Mr. Morley had referred to the question of ball bearings and their lubrication and Mr. Hepburn was convinced that for the majority of drives, there were a few exceptions, the ball and roller bearing was the correct thing. Their lubrication however required very careful attention and should not be left to causal labour: it should receive regular and systematic attention, and be one of the duties of the electrical staff under whose care the motors generally were. It would be of interest to mention a case that came to Mr. Hepburn's attention some few months ago, where a ball bearing was giving out about every three or four months. The failures occurred some three or four times for no apparent reason. The plant was a 30 or 40 h.p. motor driving a centrifugal pump through one of those so-called flexible couples. One morning it was reported that the ball housing was again very hot, which appeared to indicate a damaged or a broken ball or some foreign matter in the housing. On listening intently Mr. Hepburn felt sure that the noise did not emanate from the ball housing at all, although it was hot, and on examining the coupling found the usual signs of movement indicated by the formation of dust. The application of a little oil to the bands cooled down the ball bearing. It was one of those cases where a flexible coupling had been inserted as an excuse for bad alignment.

Mr. A. T. ROBERTSON (in reply).—The discussion furnishes abundant evidence of agreement that robust construction is of primary importance for colliery motors, and that if they are to be really satisfactory every detail must be such that reliable and convenient operation is obtained under the most adverse service conditions possible. Ample mechanical strength of frames, fans, shafts, bearings and other parts ; rigid support and fixing of cores ; the best possible insulation and impreg- of windings ; and adaptable cable-entry arrangements—

all these are essential features of colliery-motor construction, and it is only when it has to be decided how to provide these features that opinions differ.

Manufacturers will benefit by making use of the various speakers' suggestions, which are the result of their experience ; but it is not always possible to make motors that will satisfy everyone in all details. Departures from a construction approved by colliery engineers generally, to meet the desires of an individual, are often very difficult and costly, because they may entail the dislocation of manufacturing processes involving expensive plant. Most manufacturers are anxious to supply machines to meet colliery needs ; and extensive experience, research and design investigations, modern manufacturing plant, and keen competition, will ensure the supply of the best that can be produced, provided that each engineer is prepared to accept what colliery engineers as a whole agree is sound construction.

In reply to specific matters referred to in the discussion, it must be explained that the paragraph referring to the increase in size necessary on inter-frequency motors is an attempt to state the facts in a very general way, and that, strictly speaking, the problem does not lend itself to any very simple treatment, because it is influenced by a number of complicated factors, the effect of which depends upon each manufacturer's particular design of motor. The question the manufacturer has to settle is : what are the maximum outputs of standard frames used as inter-frequency motors, and how do these compare with their outputs as standard 40 cycle motors ? A frame will always give, as a minimum, 12 per cent. less than the standard 40 cycle output when used as an inter-frequency motor ; but in favourable circumstances it may actually give the full standard 40-cycle output. Whether or not a reduction of output is necessary, and what the amount of the reduction must be up to a maximum of 12 per cent, depend upon the effects of a number of factors.

If the overload capacity of an inter-frequency motor is never to fall belov the British standard of twice full-load torque, 12 per cent. additional flux will be required at 40 cycles, in frames that as standard 40-cycle motors have just twice full-load-torque overload capacity, to enable them to give the necessary overload capacity, at the same horse-power when working at 50 cycles ; but 25% additional flux will be required if the overload capacity is required on the basis of the same torque at 50 cycles as at 40 cycles. If, on the other hand, the standard 40 cycle motor already happens to have an overload-capacity of 2.5 times full-load torque, no increase in flux is necessary to give the standard overload-capacity of twice full-load torque when working at 50 cycles. Two-pole and four-pole, and some six-pole and eight-pole motors are in this category.

When additional flux is required to obtain the full overload capacity when working at 50 cycles, the possibility of maintaining the full output depends upon :

(a) Whether or not it is possible to provide the additional flux without an abnormal saturation of the core, which would reduce the power-factor and efficiency of the motor when working at 40 cycles below the specified values. This will depend upon the saturation of the core normally used, but it should be realised that even if the output is reduced, so that the motor is working at normal saturation, its power-factor and efficiency will be less at 40 cycles than those of a standard 40 cycle motor, because it is working with a larger flux than the normal for the output.

(b) Whether or not the resultant increase in the core-loss over-balances the reduction in copper-loss to such an extent that the specified temperature limits would be exceeded.

An inter-frequency motor, when working at 40 cycles, is allowed by specification to have an efficiency 2 per cent. lower than that of a standard 40-cycle motor. With efficiencies of the order of 84 per cent. this means a permissible increase in the losses of 12 per cent. ; but if the standard 40-cycle motor-output is based on the maximum allowable temperature rise, no advantage can be taken of the permitted increase in the losses. Inter-frequency motors working at 50 cycles undoubtedly have higher efficiencies and power-factors than the corresponding standard 50-cycle motors ; and this is due to their being larger than they need be for the output actually required of them at 50 cycles.

Mechanical interchangeability of motors, depending as it does on manufacturing tolerance limits, which have not been standardised in Great Britain, does not exist as a rule between one manufacturers' product and another ; but as between one machine and another made by the same manufacturer the degree of accuracy will depend entirely upon the tolerances worked to. The dimensions of most importance in this respect are : the height of the shaft-centre, which should be correct to about 0.001" for every 5" of height ; the diameter of the shaft, which should be correct to within 0.0005" to 0.0002", according to the diameter ; and centres of the feet fixing holes which should be correct within the amount of bolt slackness in the feet holes, so that it is always possible to get all four bolts into position without difficulty when changing motors.

Attempts have been made from time to time to standardise shaft dimensions for electric motors, but no agreement has yet been reached, probably because different qualities of steel are used by different manufacturers. There are two distinct purposes that a shaft must fulfil : 1. it must be stiff enough, between the bearings, to prevent undue deflection as a result of combined mechanical and magnetic pull ; 2. the extension must be strong enough to withstand the heavy stresses set up by the drive.

Some manufacturers believe that it is better to have a smaller diameter shaft-extension of high-grade steel than a larger one of normal steel, because pinions of smaller diameter can then be used without sacrificing strength.

Flexible couplings have always been a source of trouble. They do not work satisfactorily unless the driving and driven shafts are in almost exact alignment, which is not so easily obtained with a flexible coupling as with a solid coupling that had had a finishing cut taken over its exposed faces after being fitted to the shaft, because these faces can be used for checking alignment. The fact that there are so many different types of flexible couplings on the market indicates how difficult it is to make one that will operate really without trouble.

The exact limits of the satisfactory use of ball and roller bearings cannot be stated in any simple way. For smooth drives, such as can be obtained when using a rope or belt pulley, there is probably no limit, provided that suitable bearings are employed, and an outer bearing is fitted in drives that would otherwise have too great a shaft overhang.

When a motor is coupled solidly to a shaft working in sleeve bearings it should not have ball or roller bearings unless arrangements are made to ensure that the sleeve bearings take their correct share of the load. Any wear on the sleeve bearings tends to throw the load on to the ball bearings, and may set up strains in the drive. Ball bearings, however, would be quite satisfactory if a flexible coupling were used, provided, of course, that, as has already been mentioned, the two shafts are correctly aligned. Under these circumstances there is no limit to the size of motors to which ball and roller bearings can be fitted to give perfectly satisfactory service.

A motor with a steel pinion having straight cut heavy pitched teeth has perhaps the most difficult drive of all from the bearing point of view; and it is impossible to say, under such conditions, without knowledge of all the details of the drive, what is the maximum horse-power for which ball and roller bearings are suitable. With properly cut gears, meshed correctly, no trouble would be experienced; and it is only to the extent that these requirements are not satisfied that it is doubtful whether ball bearings can be relied upon to give satisfactory service with the larger powers.

It is essential that free axial movement should be allowed on the shaft of a motor solidly coupled to a worm-gear, so that the end-thrust may be taken by the thrust-bearing on the worm-shaft specially provided for that purpose. However accurately the erection is carried out, if a normal motor with a located shaft is used for such a drive, bearing trouble or worse is inevitable owing to the excessive end-thrust that must occur when the motor and gear warm up on load and cause unequal expansion of the shaft and bedplate.

To free a motor shaft from the endwise location provided as a normal feature, so that it may be suitable for a drive where end location would be disastrous, it is usual to reduce the depth of the circular projections on the bearing end-caps that normally clamp the outer race of the ball bearing. This allows the outer race to take up its correct position in the housing as determined by the worm-gear thrust bearing. Alternatively, the ball bearing can be replaced by a roller bearing, but if this is done it is inadvisable to run the motor even temporarily, say for test purposes, uncoupled from the worm-gear that provides the end location for the shaft.

The design and construction of fans has not had the attention from some manufacturers that their importance for satisfactory operation warrants. Fans built up of sheet iron are difficult to make of the most suitable shape, and are liable to be shaken to pieces or to rust away. On the other hand, cast aluminium alloy fans can be made of any desired shape without joints, suitable for equally efficient operation in either direction of rotation; and, provided they are suitably fixed to the rotor, they give reliable service without deterioration.

Solid impregnation is used by some manufacturers because it enables the heat from the copper in the slots to be more easily conducted to the core, and so reduces the size of the motor required for a given output and temperature rise. The chief objection to its use is the impossibility of repairing a winding without making a total rewind, which means that, since the size of the motor has been fixed on the assumption that the windings will be solidly impregnated, the temperature rise after the rewind will be higher unless they are solidly impregnated again.

Terminal boxes are usually made so that the cable entry can be turned to suit a cable lead coming up, or down, or sideways from the right or left. Universal cable glands are available, each suitable for a range of sizes of three-core V.I.R. bitumen or P.I.L.C.. cables, with either single or double wire armouring, and are made so that lead-wool packing can be used for convenience instead of a wiped joint.

CUMBERLAND SUB-BRANCH.

Electrical Breakdowns and Repairs.

J. WALKER.

A most enjoyable evening was spent on March 4th when Mr. J. Walker of Edinburgh delivered a Lecture entitled Electrical Breakdowns and Repairs. The occasion drew a record attendance and the interest of the members was evinced by the excellent discussion that ensued. Mr. Walker dealt with his subject in his own interesting and inimicable manner and, in addition to shewing some 150 lantern slides, exhibited a large number of actual specimens of faulty apparatus that he had encountered during his experience.

A hearty vote of thanks from the members and committee was proposed by Mr. A. R. Hill, who expressed the keen appreciation of all present of Mr. Walker's effort. The lucidity of his remarks, and the clarity of his reasonings and arguments, were an example to all that gave papers.

The vote was seconded by Mr. Wescott and carried with acclamation.

Mr. Walker, in responding, expressed his pleasure at being present and emphasised that he was only too willing to do anything he possibly could to further the interests of The Association.

YORKSHIRE BRANCH.

At a meeting of this Branch held in the Technical College, Leeds, on 5th December last, Mr. R. T. Ringrose B.Sc., gave a valuable series of demonstrations with his wellknown fire-damp detectors and alarms. The lecture was largely based upon the paper which Mr. Ringrose read at a meeting of the Cumberland Sub-Branch of the Association and which is reported in full in *The Mining Electrical Engineer*, September, 1931, page 102. In addition to repeating the description of the application of the "gas sentinel" to a motor starter, Mr. Ringrose introduced Mr. H. Copping who thereafter explained, with the aid of a demonstration model, certain improvements which had been made in applying the gas sentinel protective gear to an Ellison flame-proof, oil-circuit breaker.

Automatic Gas Alarms.

Discussion.

Mr. J. R. TOMMIS (Branch Vice-President) introduced the discussion by expressing appreciation of the most interesting paper and valuable demonstrations by Mr. Ringrose of his system of automatic firedamp detection.

Mr. HIGGENS said he was surprised to hear from the lecturer that there had been more explosions of late years.

Mr. RINGROSE replied that explosions of inflammable gas had been more frequent, but less serious owing to the effects being localised by the extensive use of stone dusting. The cause of practically all recent explosions had been primarily inflammable gas.

Mr. HIGGENS asked the reason for the production of the vacuum inside the porous pot through the burning of methane. Did the CO_2 diffuse out at the same rate as the air diffused in? Combustion of methane produces CO_2 and water, and the vapour formed condensed producing a partial vacuum. Why then did not the reduction in pressure increase indefinitely? The lamp, he understood was not intended to serve an illuminating purpose, but only as a gas alarm. It would therefore seem that a workman would have one ordinary lamp and one alarm, or one alarm for a party of men. They were extremely fortunate in having heard such a valuable paper, and particularly as it had been given by the person responsible for the invention of the apparatus.

Mr. RINGROSE, in reply to Mr. Higgens, said that the quantity of water formed was insignificantly small as the amount of inflammable gas that passes into the interior of the pot was so very little; in fact after the apparatus has been in use in a gas mixture for a long period, only a very fine film of moisture could be observed. The vacuum inside the pot was the result of the combustion which was not increasing indefinitely owing to the pot being porous. Thus a differential vacuum was set up exactly proportional to the percentage of gas surrounding the apparatus.

In his opinion there should be one gas alarm for about every ten workmen, and the alarm should be hung up in a high position in the workings.

Mr. MANN referred to the frequency of accidents and indicated that whilst there had been more, due to the introduction of electricity into the mines, nevertheless there had been a proportionate reduction as compared with the increasing horse-power installed. With regard to the gas sentinel detector; a switch off may be caused by either the gas fuse blowing or overload. Was there not some risk of panic, as the workman might naturally assume that the detector had operated by gas, when in point of fact it might have been merely a circuit overload?

Regarding the breaker on view, Mr. Mann asked whether they were to understand that the lamps were to be used as a resistance or was some non inductive type of resistance to be used for, under the C.M.A., no lamp was allowed within 300 yards of the working face. Was it intended to fit the sentinel on to the gate-end switch box? That was usually a low place and it would be preferable to raise the sentinel as much as possible or to fix it on to the coalcutter. It was a disadvantage to have to change the filament every day. Were all parts of the lamp of non-ferrous material? Owing to the dampness of most mines ferrous parts would be affected by corrosion.

Mr. RINGROSE.—When first used, the lamp was set to work at 1¼% of gas; that meant that the contacts had to be extremely close together, and as the apparatus depended upon vacuum, the alarm would operate due to increased pressure on descending a shaft, but it went "off" again in a few seconds when the pressure inside and outside the porous pot regained balance. The new alarm was set to operate above 2½%, and was therefore not so sensitive. The alarm filament should be changed every shift, but the filament of the sentinel would operate for at least 300 hours. There was no ferrous material in the alarm, except a spring, and this could easily be made of phosphor bronze. There was no difficulty in arranging things so that it would be easy to ascertain the cause of the tripping of the overload, whether by gas or for any other reason.

Mr. COPPING.—With the circuit breaker shewn, the workmen would have no indication as to whether the stoppage was due to fuse overload or the sentinel, but that should not cause panic as there should be some other detector in the vicinity.

The breaker demonstrated was fitted up for show purposes only and illustrated how the sentinel could be attached to the standard type of breaker. The sentinel took about 1½ amperes and the lamps in the model were only there to reduce the current in the filament; the same could be obtained by a non-inductive resistance or relay with sufficient impedence.

Mr. RINGROSE said the best method of lighting the coal face was very open to debate: if the sentinel were to be attached to the coalcutter then pilot wires would be required.

Mr. CARTER said he did not think the sentinel will do away with the necessity for flame-proof switchgear. The flanges were intended to cool the gases should an explosion take place in the machine, such as an internal short circuit. He was of the opinion that in the near future flame-proof apparatus would be as cheap as the ordinary type; as the demand increased so mass production would cheapen the manufacture and provide moreover a much stronger piece of apparatus.

Mr. RINGROSE said the sentinel was not intended to supplant flame-proof apparatus but was to act as a supplementary device.

Mr. MAWSON.—Are the filaments made of platinum?

Mr. RINGROSE.—Either platinum or palladium.

Mr. DAWSON had experience with a sentinel fixed to a face plate starter, but had trouble at first due to the burning of the filament. That was due to the lamps having less resistance when cold than when burning, resulting in excessive current at the start. The sentinel was fitted with a stronger filament and went very well. The first specimen was fitted to a 500 volt d.c. circuit and clearances were very small and faults developed due to moisture. Slate was fitted instead of the usual insulators, and it ran for twelve months without trouble. It was out of action at the present time due to a short on the lamp cable. The sentinel was not operated at any time by natural gas, but on taking gas to it, it functioned instantly.

Mr. RINGROSE.—The lamps used by Mr. Dawson were metallic filament lamps and a "flash-over" burnt the interior of the detector. That would not occur with an a.c. circuit and the sentinel could be more easily adapted.

SOUTH WALES BRANCH.

(P) Copper and Aluminium.

B. J. BURKLE.

(Associate.)

(*Paper read* 16*th January*, 1932.)

One of the notable effects of the remarkable developments in aviation, motoring, and electrical engineering during the past twenty years has been the bringing the metal aluminium into world-wide prominence. Recently the engineers responsible for the erection of the British "Grid" have amplified this prominence by adopting steel-cored aluminium conductors for their entire system. Whilst this has greatly emphasised one particular application of aluminium, it has also resulted in other applications too important to be kept in obscurity. In all its applications a comparison with the metals which aluminium is supplanting or supplementing is well worth the time and trouble taken. In this paper it is proposed to review briefly the production and properties of aluminium and copper, and to give also a brief account of some of the applications of aluminium that are of interest to the electrical engineer. Iron and steel have for so long been the servants of man that any account of their production is not necessary in this instance.

Commercial Production of Copper.

Copper is often found "native" that is, in a metallic form in nature, but it is generally obtained by smelting from compounds in ores, in which forms it is found combined with sulphur as sulphide, or with oxygen as oxide. Such metallic ores frequently contain small quantities of sulphur, lead, bismuth, arsenic, and iron, and occasionally traces of gold and silver.

The most economical commercial method of preparing pure copper is to prepare an impure compound, such as blister copper by metallurgical or furnace methods and to refine the product by electrolytic means. The copper used for conductors in electrical work has to be absolutely pure, so that, as there is no more successful method of refining copper than by electrolytic methods, more and more of the world's production of copper is so refined.

The universal principle underlying the various processes of electrolytically refining copper may be said to consist in the passing of an electric current of suitable strength through a solution of copper sulphate, acidulated with sulphuric acid. The current passes from an anode of the metal to be refined, through the solution, to a suitable cathode upon which the pure metal is deposited. Allowance is made for the removal of such impurities as may form a slimy sediment in the bottom of the vat, and for the prevention of the excessive accumulation of solid impurities in the electrolyte. Many variations in the application of this principle are possible much depending on the nature of the compound refined.

Production of Aluminium.

The modern commercial method of producing aluminium consists of, firstly the preparation of pure alumina (aluminium oxide) from the mineral ore and, secondly, the electric dissociation of the alumina.

It has been estimated that approximately one-eighth of the world's crust consists of aluminium in chemical combination with other elements, chiefly as an oxide, but only one mineral—bauxite—is at present used in the commercial production of aluminium. Bauxite, which usually contains about 60 per cent. of alumina, and impurities which can be economically removed, is found in large deposits in British Guiana, South of France Gold Coast Colony, India, Hungary, Italy and, in a less pure form, in America.

By a wet chemical process the alumina is isolated from the ore, the ultimate result of the process being that a fine white anhydrous powder is obtained. The second process, that of reducing the alumina, is a continuous one for which a bulk supply of electric power at a low rate is of the utmost necessity. A large open bath of refractory brick, lined with carbon, is employed, the carbon forming the cathode of the cell. Carbon blocks, set above the open top so that their height can be adjusted at will, form the anodes. The cell is packed with a mixture of alumina and cryolite, the sole purpose of the latter being to serve as a flux or solvent for the alumina. The current passing between the anode and the cathode readily fuses this mixture, maintains it in fusion, and at the same time dissociates the alumina into two elements, aluminium and oxygen. The metal is deposited in molten form on the floor of the bath from whence it is tapped off at intervals and cast into various forms of marketable ingots. To obtain the highest degree of purity of the metal extreme care is taken in the choice of raw materials and in the working of the entire process. The purity of the aluminium used for electrical purposes is as high as 99.6 per cent.

TABLE I.

Metal	Degree of purity or Composition if an alloy	Specific Gravity	Modulus of Elasticity
Copper ...	—	... 8.89	... 18×10^6 lbs. sq. in.
Aluminium...	99.66% pure	... 2.705	... 9.9×10^6 lbs. sq. in.
Aldrey ...	0.5%Si., 0.3%Fe., 0.5%Mg., 98.7%Al	... 2.710	... 9.02×10^6 lbs. sq. in.

TABLE II.

Metal	Relative Conductivity	Specific Resistance at 20 degree C.	Temp. Coefficient of Electrical Resistance per degree C.
Copper ...	100	... 1.731 microhms, c.m.cube	... 0.00401
Aluminium...	62	... 2.874 microhms, c.m.cube	... 0.00407
Aldrey ...	50	... 3.42 microhms, c.m.cube	... 0.0036

Properties of Copper and Aluminium, and their Alloys of these metals.

Table No. 1 gives some details of the physical properties of the metals; Table No. II. gives some electrical constants. Copper, with the exception of silver, is the best known conductor of heat and electricity. When annealed it is inclined to be brittle, but if heated and cooled rapidly it is extremely soft and ductile. It possesses considerable tenacity but this falls off rapidly when it is heated. Dry air has no action upon it but in the presence of moisture and carbon dioxide it becomes corroded and coated with a deposit of basic carbonate. This is the greenish coating that copper acquires when exposed to the vagaries of our climate.

The outstanding physical property of aluminium is its light weight. The specific gravity is 2.705 as compared with 8.89 for copper, so that bulk for bulk aluminium is slightly less than one third the weight of copper. The majority of the aluminium alloys, which rarely contain more than 10 per cent. of added metals, also possess in varying degrees this frequently advantageous property.

The non-magnetic metals available for commercial use are somewhat limited in number and are practically confined to the brasses and bronzes, the non-magnetic irons and steels, the alloys of aluminium, and copper and aluminium.

An important property of aluminium in the pure form is an almost extremely ductility. Pure aluminium can be worked into almost inconceivable shapes without any annealing process. For instance the motor car body builder uses the metal to produce the graceful streamline bodywork of the racing car; it is also used for intricate shapes such as wireless valves, vacuum cleaners, etc., of the advertising tradesmen's delivery van.

More important in many respects than its ductility is the resistance that aluminium offers to corrosive influences. To the attacks of many chemical substances it presents a surface that is almost glass-like. This explains the extensive use that has been found for the metal in industrial chemical plants of all kinds. The housewife finds, too, that it is the safest and most hygienic metal available for cooking utensils and for vessels used for the storage of food.

The corrosion resistance of aluminium is due to the formation of a film of oxide on the surface of the metal. This film is closely adherent and its thickness adjusts itself to the corrosive influences. The film is microscopically thin on a brightly polished piece of metal kept indoors, but on metal exposed out of doors the film will thicken up until it becomes a readily visible greyish coating. Once the thickness is sufficient to provide adequate protection no further action takes place. Thus, aluminium overhead line conductors have been in use, exposed to the weather, for more than thirty years without alteration once the protective film has thickened to the requisite amount.

The electrical conductivity of aluminium is approximately 60 per cent. of that of copper but as its specific gravity is slightly less than one third that of copper it follows that one pound of aluminium is equivalent electrically to two pounds of copper. On the other hand, in direct comparison with copper, for the same conductivity a diameter 27 per cent. greater, or an area 64 per cent. greater is required, while the tensile strength only amounts to 63 per cent. of the equivalent copper wire. It may therefore be readily seen that with its relative advantages and disadvantages aluminium must be considered not as a material which will supplant copper as a conductor, but rather as one that will supplement it ; the advantages becoming apparent where light weight and large radiating surface are desirable, whereas should strength and small diameter be essential its use is not permissible.

Some Applications of the Metals.

The immediately foregoing paragraph clearly indicates that copper is the most economical material to use in the manufacture of insulated cables. The additional cost of the extra insulation that would be necessary if aluminium conductors were used far outweighs the saving that might be made in the actual metal of the conductors.

The low melting point of aluminium prohibits its use for switch and controller contacts. In this field copper and brass reign supreme as they withstand the effect of arcing for a considerable time. It is clear that such a characteristic as lightness is of little or no advantage in stationary contacts, but in the moving parts of a quick acting switch it is of extreme importance as the use of a light cross-head and cross-arms carrying the contact shoes will result in a quicker break being possible for the same strength of acceleration spring. Furthermore light weight will enable the cross-arm to be brought to rest with the minimum of shock. It is found that the stresses set up in the moving parts are directly proportional to the weight moved as well as to the acceleration ; so that by using some alloy of aluminium it would be possible to double the rate of acceleration, while still reducing the stresses set up, because the inertia would be reduced by almost one-third. The use of an alloy is advocated because the forces involved are much too great to permit the use of such a comparatively weak metal as pure aluminium. The actual alloy selected depends to a great extent on the designers, some of whom prefer duralumin because of its very small ratio of weight to strength, while others advocate the use of a silicon alloy, pointing out that its cost is smaller and that although a heavier casting has to be employed the weight does not reach unreasonable proportions, because of the fact that the silicon alloy possesses a very high mechanical shock resistance.

An application of aluminium that, while not being of very great interest to the mining electrical engineer, is of considerable importance, is its use in the components of rolling stock of all kinds. Aluminium is frequently used in parts of the motors, control gear, and other electrical equipment of vehicles of all kinds in order to reduce the deadweight, which is oftentimes greater than the paying part of the load. It is generally agreed that lightness is desirable even though an increase in first cost is involved. Methods by which the deadweight of vehicles is reduced vary greatly but it is generally agreed that the use of aluminium, or one or other of its alloys, instead of iron and steel for many parts of the electrical equipments of all forms of vehicle is a sound economical proposition.

It is interesting in passing to note that when introduced on the London omnibuses, aluminium wheels proved an outstanding success, a wheel having a life of more than 90,000 road miles.

It sometimes happens that an extremely light electric motor is required. In such cases the carcase can be cast from an aluminium alloy, and if the motor is a d.c. one, it is quite possible to replace the usual copper field coils with aluminium ones of exactly the same external dimensions, resistance, and number of turns. This is possible because of the fact that aluminium wire can be provided with an artificially increased thickness of oxide on the surface which, though extremely thin, is an insulator of the first class and the necessity for any additional fibrous insulation is eliminated. It is permissible to run such coils at a much higher temperature than those of copper, as the oxide is quite unaffected by heat up to the melting point of aluminium.

In the case of squirrel cage motors up to about 25 h.p., the use of aluminium for the rotor conductors is an economical proposition because of the reduced manufacturing costs. The process adopted when aluminium is used is to place the assembled rotor laminations in a suitable mould and to pour in molten aluminium. Thus no soldering or brazing of the conductors to the end rings has to be done, as is the case with copper. Some manufacturers use one of the silicon alloys, because of their superiority over pure aluminium for casting purposes, but the lower electrical resistivity of the latter is a desirable advantage, and to obtain which various methods for counteracting the shrinkage effects on solidifying have been evolved. Some manufacturers cast the metal while the mould is being rapidly rotated, while others prefer simply to leave sufficient slackness in the laminations when placing them in the mould so that no resistance is offered to the contracting aluminium.

In designing the rotors of large alternators of 50,000 k.w. and over, great difficulties are met with in overcoming the enormous centrifugal forces which tend to force the conductors out of their slots. Some manufacturers use massive alloy steel retaining rings to ensure safety. Others reduce the centrifugal forces by reducing the weight of the windings, aluminium being used. In such machines there is invariably sufficient room to accommodate the extra 60 per cent of conductor metal. Duralumin is often used in such cases for the wedges holding the conductors in the slots.

Colliery electricians know only too well the usefulness of the "Meg" insulation tester, weighing only 7 lbs. in all. The generator parts and the casing of this instrument are made of aluminium.

Turning to the applications of aluminium in which the ductility of the metal is the main reason for its adoption, it is found that press drawing from aluminium sheet is the most economical method of manufacturing meter cases. Unlike brass, which is also considered a good metal for press work, aluminium does not harden up when much forming is done. This obviates the necessity for working in easy stages with intermediate annealing in between.

The applications of aluminium in which a reduction in the cost of the finished article is a direct result of the choice of the metal are numerous. Certain of the aluminium alloys are very suitable for casting in metal moulds; the casting produced being accurate in size and requiring little or no machining. Such things as magneto casings, machine name plates, handwheels, handles, switchboard wiring cleats, and all kinds of boxes and covers, made in this way are cheap and may be made very effective in appearance by enamelling or polishing, a form of finish quite easily brought to a very high standard on aluminium. Again, the ease with which aluminium can be machined often results in the finished article being cheaper when made in aluminium than when iron is used. Machining costs with iron may oftentimes exceed the cost of the actual casting, thus sending up the total cost considerably.

Aluminium has another characteristic that is of very great value in electrical engineering. In its pure form the metal has a magnetic susceptibility of 0.65×10^6. This means that the metal is by far the most suitable known metal for the construction of certain parts of large metal-clad a.c. gear in which each phase is separately encased. It is essential with this class of gear that the casing be partly or wholly of some non-magnetic material as otherwise the alternating magnetisation of the metal sets up eddy currents and hysterisis losses which may be considerable when current of more than 400 amps. flow in the conductor. When all three conductors of a three-phase system are enclosed in the same casing with no dividing wall between them the magnetic path between the conductors is of such a high reluctance that the flux set up in the casing is negligible and it becomes unnecessary to use a non-magnetic material.

The currents met with in mining electrical engineering may not be of sufficient magnitude to cause serious trouble due to the effects of the magnetic fields set up in any iron or steel in the vicinity of the conductors, but in electric furnace practice cases have been met with when even the roof trusses of the buildings housing the apparatus have had, of necessity, to be made of some non-magnetic material.

Bus-Bars.

Considerable care has to be exercised in the design of bus-bar systems in which very heavy currents may flow should a short circuit occur on the feeders supplied from the bars. Such an occurrence might result in the setting up of mechanical forces of considerable magnitude between the bars. A method by which such forces may be calculated is as follows :—

Assuming round bars are being used (strip conductors would result in the repulsive force being slightly less because of the different formation of the magnetic field) in the event of

(1) The short circuit being across one phase :—

$$F = \frac{10.8 \times I_s^2}{d \times 10^7}$$

(2) The short circuit being across three phases, and the bus-bars being in triangular formation :—

$$F = \frac{9.342 \times I_s^2}{d \times 10^7}$$

(3) The short circuit being across three phases, and the bus-bars being in the same plane :—

$$F = \frac{8.078 \times I_s^2}{d \times 10^7}$$

where F = maximum repulsive force in lbs. per foot run.
d = distance between conductors in inches.
I_s = RMS value of the current flowing.

The above formulæ serve for alternating currents; for d.c. the value of F should be halved.

The value of I_s may become exceedingly high. Should the fault occur on the bus-bars of a three-phase system I_s will practically amount to the short circuit current of the generating plant, i.e., it will be from five to twenty times the normal full load current.

To give a simple numerical example. Should the short circuit be across one phase, I_s = 100,000 amperes, d = 10 inches, then F would amount to 1080 lbs. per foot run.

The rigidity of the bars, the insulators and their supports is therefore a matter of some importance. A simple method of comparing the rigidity of copper and aluminium bars is to imagine a copper and an aluminium bar of similar width but of once and a half times the thickness (this to give the necessary conductivity) side by side and carrying equal currents, the section modulus of the aluminium bar is two and a quarter times that of the copper bar, so that the stress in the latter will be two and a quarter times that in the former. The elastic limit of copper may be taken as twice that of aluminium so that when the action of the force between the bars reaches a value at which the copper bar is loaded to its elastic limit the aluminium one is still well within the bounds of its elastic limit.

For loads that lie within the elastic limit, and for the same conditions of installation such as the distance between the supports, it can be shewn that aluminium is even more rigid than copper. In making the calculations involved it is necessary to regard the bars as beams. The deflection at the centre of a beam is inversely proportional to the product of the moment of inertia of the section, I_n, and the modulus of elasticity M, of the material. Remembering that the aluminium bar is one and a half times the thickness of the copper bar, then the moment of inertia of the aluminium bar is 3.38 times that of the copper bar. It follows that the product $I_n M$ for the aluminium bar will be 1.81 times that of the copper bar. In other words, the copper bar will, for a given load, be deflected from a straight line by more than one and a half times as much as the aluminium bar.

The problems met with in designing a bus-bar system are not entirely of a mechanical nature. The current carrying capacity of the bars depends principally on the permissible temperature rise, and therefore on the cross sectional area and the effective radiating surface of the bars. A strip laid vertically on edge forms the ideal bus-bar, as in that position it will carry more current than a strip laid in a flat or horizontal position, the difference being as much as 9%.

To increase the radiating surface a large conductor is sometimes replaced by several smaller ones, thus allowing the total cross sectional area to be reduced. Further improvement in heat radiation is obtained by giving the bar a coating of dull black paint. Tables Nos. III. and IV. are based on these conditions and are due to Messrs. Melsom & Booth, who included them in a very interesting paper which appeared in the I.E.E. Journal for November, 1924. An air temperature of

TABLE III.

Current Carrying Capacity of Flat Copper Bars with Dull Black Surface.

Dimensions Thickness inch	Breadth inches	Area sq. inches	Current Carrying Capacity Amps.	Current Density Amps. per sq. inch
1/4	1	0.25	439	1760
	1½	0.375	623	1664
	2	0.5	803	1607
	2½	0.625	973	1558
	3	0.75	1148	1532
1/8	1	0.125	298	2380
	1½	0.1875	428	2280
	2	0.250	553	2210
	2½	0.3125	648	2190
	3	0.375	802	2130

TABLE IV.

Current Carrying Capacity of Flat Aluminium Bars with Dull Black Surface.

Dimensions Thickness inch	Breadth inches	Area sq. inches	Current Carrying Capacity Amps.	Current Density Amps. per sq. inch
3/8	1¼	0.469	530	1130
	1½	0.563	610	1080
	2	0.75	780	1040
	2½	0.935	945	1010
	3	1.126	1110	985
3/16	1	0.188	290	1543
1/8	¾	0.094	203	2160
	1	0.125	255	2040
	1¼	0.156	281	1800
	2	0.250	430	1714

104 degs. F. is assumed and a rise of 54 degs. F. in five or six hours is taken as permissible. The values given in these tables should be reduced by 20% to 25% if the bars are unpainted and are polished to any degree.

With alternating current an effect known as "skin effect" has to be allowed for. For currents of 50 cycles a reduction of from 2% to 5%, depending on the size of the bar, in the carrying capacity has to be made, and with aluminium bars a reduction of from 1% to 5% is necessary.

When installing some allowance should be made for expansion, as a temperature rise of 54 degs. F. gives an increase in length of 0.3 inch per 50 ft. length of copper and .4 inch per 50 ft. length of aluminium.

Much of the foregoing seems to indicate that aluminium is superior, or at least equal to, copper as a material for bus-bars, but cases have been met with in practice which clearly indicate the opposite. For instance in a scheme installed some twenty odd years ago, so much trouble was experienced, due to heating at the joints, that the whole of the aluminium work was scrapped. The heating at the joints was caused by oxidisation setting in, producing a white film of very high resistance. It was in fact a case of electrolysis, set up by a humid atmosphere and the use of clamping bolts of a material different from that of the bars. Such troubles are, however, rarely met with in more modern installations, as research has resulted in a metal of a higher degree of purity being available; and of course adopting the obvious method of using only bolts of the same metal as the bars, thereby removing the possibility of electrolysis. It is interesting to note that the most satisfactory method of making a joint in aluminium rod is by butt welding, a process that is very easily carried out with the metal owing to its comparatively low melting point.

Overhead Lines.

The quantity of literature available on the subject of electric power transmission is surprisingly small when compared with that on power generation. Almost every other branch of electrical engineering seems to have attracted many more of our expert technicians: there is some grounds for regret in noting that many of the recent and outstanding developments are due to experiments and investigations conducted abroad. One of the most striking developments of the past few years has been the extensive adoption of composite conductors on almost all types of transmission line.

The best known, and most frequently used, composite conductors are (1) Copper Clad Steel and (2) Steel Cored Aluminium.

(1) In the manufacture of copper clad steel conductors a six inch diameter steel billet is dipped into molten copper at a temperature of from 1500 degs. C. to 1600 degs. C. and is allowed to remain long enough for the copper to adhere to the surface of the steel. The whole mass is then rolled and drawn, both metals being compelled to elongate by the same amount, thus producing a wire that has a steel core and a copper covering. The only advantage that this type of conductor has over hard drawn copper wire is that it has a much higher tensile strength. On the other hand it has a much greater surface area for the same conductivity and consequently a larger effective surface area is exposed to wind pressure and ice loading. This type of conductor is not used very extensively in this country.

(2) Steel cored aluminium conductors are manufactured in various ways but consist essentially of a core of high tensile steel, made up of one or more wires, around which are laid up the aluminium wires. Generally the steel and aluminium wires are all of the same diameter, the simplest and most common ratio of steel to aluminium being one to six. The steel section is ignored when the current carrying capacity of the composite conductor is being estimated; the breaking load of the conductor has been found to be equal to 98% of the total strength of the aluminium conductors, plus the breaking load of the steel conductors, less 15%. To obtain the best quality conductor the steel wires, the tensile strength of which ranges from 150,000 lbs. to 200,000 lbs. per square inch, depending on the size of the conductor, should be galvanised by the "Crapo" process.

A comparison between the costs of copper and aluminium lines already erected has frequently proved the latter to be the more economical, the percentage economy being dependent on market conditions. And, to a lesser degree, certain other factors. When making such a comparison it is necessary to consider the comparative periods of useful life and the scrap value of the materials. The life of steel cored aluminium is slightly less than that of copper while the scrap value of aluminium is exceedingly low.

The saving in initial cost is not the only factor that led to the adoption of steel cored aluminium conductors for such important schemes as the British "Grid" and the lines of the Electricity Commission of Victoria, Australia. It can definitely be proved to be as good as, if not superior to, copper for many lines when regarded purely from a technical standpoint. While it is generally agreed that particular problems requiring individual treatment occur with almost every transmission line erected, it is possible to classify all types of line under three headings, namely :—

(1) Main trunk or "Grid" lines utilising voltages of from 33,000 to 250,000 volts.

(2) Subsidiary lines using voltages up to 33,000 volts.

(3) Small lines such as are used for rural electrification.

(1) *Main Trunk Lines.*

In this case the question might be asked "Why are steel cored aluminium conductors being so extensively used on this type of line?" The answer may be summarised in three words—economy, efficiency, and reliability. It is clear that if economy is obtainable without loss of efficiency or reliability for a similar period of useful life, then steel cored aluminium will invariably be chosen.

Improvement in the design of insulators and the greater use of steel supports had added impetus to the modern tendency to make use of longer spans than has hitherto been customary. Long span construction, if well designed and erected, invariably proves to be most economical, as by its adoption a reduction in the cost of construction and in the wayleave charges is obtained, in addition to the improved reliability consequent upon the reduction in the number of insulator points. The conductors used on these long spans must, of necessity, be of very high tensile strength. In this respect copper is vastly inferior to steel cored aluminium, the latter being over 50 per cent. stronger and 20 per cent. lighter for equal conductivity.

The use of the lighter and mechanically stronger conductor enables a reduction in the sag of the conductor to be made, which in turn results in either, a reduction in the height of the supports for the same ground clearance, or a reduction in the number of supports used. The reduction in the number of supports may be as high as 25 per cent. and a corresponding reduction in the total cost of wayleaves, insulators, foundations, and general erection ensues. Individual supports would be more costly but the nett result is a distinct saving.

The fullest advantage of the superior mechanical properties of steel cored aluminium is not always utilised in making the spans longer, but even in these cases the use of the stronger conductor adds to the reliability of the line. To give an illustration: if the working load on a copper conductor is 5000 lbs., and the breaking load 10,000 lbs., giving a factor of safety of 2, there would be a margin of 5000 lbs. to take care of abnormal loads. With the equivalent steel cored aluminium conductor the breaking load would be 50 per cent. higher namely 15000 lbs. and the margin for abnormal loads would be 10,000 lbs.

Another important point with these high voltage lines is the higher corona limit of steel cored aluminium.

(2) *Subsidiary Lines.*

This is the type of line that is of most interest to mining electrical engineers as most of the H.T. lines found on and around colliery undertakings come under this category. Current carrying capacity is the main factor governing the cost of this type of line. While the type of country over which the line is run will have some influence on the cost, these lines are in general, too short for such influences to be very great.

Usually there are too many angle supports and tapping points to permit the use of long span construction, with the ultimate result that copper becomes the most economical conductor. Again, copper greatly simplifies the work at the tapping points. The apparatus to which the line is connected at these tapping points is almost invariably provided with copper connections so that if aluminium were used for the line special precautions would have to be taken to prevent the possibility of electrolysis. The extra expense so incurred would hardly be justified.

(3) *Small Lines.*

Of late, rural electrification has been receiving considerable attention; the small lines involved in such work have been the subject of much experimenting and discussion. Various metals have been tried with varying success. Galvanised iron wires proved satisfactory for some reasons but they lacked the necessary conductivity. On the whole copper remains the general favourite, as the span length never exceeds 250 feet; and, as copper has for a given conductivity a smaller diameter than conductors of other materials, it subjects the poles to a minimum of stress due to wind loads. Also, tapping points are even more frequent on this type of line than they are on subsidiary lines.

Research.

The present tendency of research seems to be towards finding a conductor possessing the mechanical properties of steel cored aluminium without having the steel core. An aluminium alloy that is being extensively used on the Continent is the ½ per cent. magnesium alloy known as "Aldrey". This is being used without a steel core and appears to be giving a fair amount of satisfaction. Its behaviour when exposed to the London atmosphere is being investigated at the present time but there seems to be little or no attempt to use "Aldrey" commercially in this country as yet.

APPENDIX.

On the suggestion and with the assistance of Mr. J. B. J. Higham, the following explanation of how the formulæ for calculating the forces between busbars in the event of short circuit are obtained from first principles, is submitted.

In Case I., the short circuit is across one phase, the conductors straight and parallel, the currents equal in magnitude and flowing in opposite directions. It is assumed that the conductors are of circular section and that their diameter is small compared with the distance between their centres. Also, that the conductors are not enclosed by, or have interposed, any magnetic material. Under these conditions the lines of force surrounding each conductor may be assumed concentric with the conductor (Fig. 1).

Fig. 1.

Fig. 2.

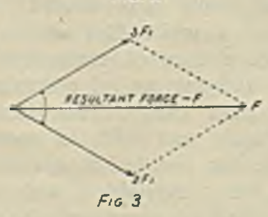


Fig 3

Fig. 4.

The force acting on each conductor is proportional to the current carried and the strength of the magnetic field at the place where it is situated. In diagram Fig. 1, the force on each cm. of No. 2 conductor is given by the expression: $F = HI_2$; where F is in dynes; I_2 is absolute amperes carried by No. 2 conductor; and H is the field strength in lines per sq. cm. due to No. 1 conductor.

$H = \frac{2I_1}{d}$ at distance d cms. from the centre of conductor No. 1. Assuming the field strength to be H, then in carrying unit N pole around the circular path of radius d cms., the work done $= H\,2\pi d$. The work done in carrying unit N pole round the conductor $= 4\pi I_1$.

$$\therefore H\,2\pi d = 4\pi I_1$$

$$\text{and } H = \frac{2I_1}{d},$$

i.e. H varies inversely as the radius, d.

$$\text{Hence, F (dynes)} = \frac{2I_1\,I_2}{d}$$

but $I_1 = I_2$,

$$\text{and F (dynes)} = \frac{2I_1^2}{d} = \frac{2I_2^2}{d}$$

With a.c. (sine wave) $I_{(RMS)} = I_{MAX}/\sqrt{2}$
and $2I^2 = I^2_{MAX}$

$\therefore$ Maximum instantaneous force—
$F = 4I^2/d$ dynes per cm. length.

Consider a one foot length of conductor run spaced at a distance d inches.

Now 1 lb. $= 981 \times 453.6$ dynes
$= 445{,}000$ dynes (approx.)

Also 1 ampere = 1/10 absolute ampere

Hence, F (in lbs. per foot run)

$$= \frac{4 \times 12 \times 2.54 \times I^2}{4.45000 \times 2.54 \times 100^2 \times D}$$

$$= \frac{48 \times I^2}{4.45 \times d \times 10^7}$$

$$= \frac{10.8\ I^2}{d \times 10^7}$$

In Case II., the short circuit is across three phases and the busbars in triangular (equilateral) formation (Fig. 2).

When the current in conductor I is at its maximum value the currents in conductor II and III are at half their maximum value.

As in Case I., the field strength at II and III can be determined: thus

$${}_1H_2 = \frac{2\sqrt{2}\,I}{10d}$$

$$\therefore {}_1F_2 = \frac{2\sqrt{2}\,I}{10d} \times \frac{.5\sqrt{2}\,I}{10} \times {}_1 = {}_2F_1$$

$$= \frac{2I^2{}_1}{100d}$$

$$\text{Also } {}_1H_3 = \frac{2\sqrt{2}{}_1}{10d} \text{ and } {}_1F_3 = \frac{2I^2{}_1}{100d} = {}_3F_1.$$

These forces are in directions inclined at 60 deg. F. (Fig. 3).

$$F = \text{Resultant Force} = \frac{2\sqrt{3}\,I^2{}_1}{100d}$$

$$= \frac{2 \times \sqrt{3} \times 12 \times 2.54}{100 \times 2.54 \times 445{,}000} \times \frac{I^2}{d}$$

$$= \frac{9.34\ I^2}{d \times 10^7}$$

In Case III., the short circuit is across three phases and the busbars in the same plane (Fig. 4).

Again, when the current in conductor I is at its maximum value the currents in conductors II and III are at half their maximum values.

As before the field strengths at II and III can be determined: thus

$${}_1H_2 = \frac{2\,Im}{10d}$$

$$\text{i.e. } {}_1F_2 = \frac{2\,Im}{10d} \times \frac{.5\,Im}{10} \times {}_1 = {}_2F_1$$

$$\text{and } {}_1H_3 = \frac{2\,Im}{20d}$$

$$\text{i.e. } {}_1F_3 = \frac{2\,Im}{20d} \times \frac{.5\,Im}{10} \times \quad = {}_3F_1$$

Total force on I due to II and III

$$= \frac{3\,I^2m{}_1}{200d} = F$$

$$\text{Now, } I = \sqrt{2}\,Im$$

$$\therefore F = \frac{6\,I^2{}_1}{200d} \text{ dynes}$$

$$= \frac{6 \times 12 \times 2.54 \times I^2}{200 \times 445{,}000 \times 2.54 \times d} \text{ lbs. per foot run}$$

$$= \frac{8.078 \times I^2}{d \times 10^7} \text{ lbs. per foot run.}$$

Note.—In Cases II. and III., ${}_1F_2$ means the force acting on busbar II as a result of its carrying a current of $\frac{0.5\,Im}{10}$ amperes when situated in a field due to a current Im in bar I.

${}_1H_2$ represents the intensity of the field at bar II due to current in bar I.

AYRSHIRE SUB-BRANCH.

Electric Lighting in Mines.

ALEX. McPHAIL.

(*Paper read 23rd January,* 1932.)

In the lighting of shaft bottom, lyes, and main roads, much power would be wasted if the lamps were to be kept lighted in all these places at all times. It is

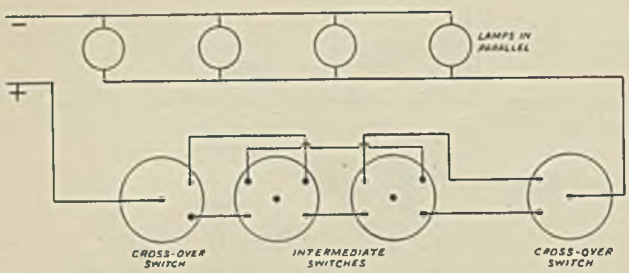


Fig. 1.

difficult to see any other way out of the trouble than to keep the lights on if workmen are passing to or from their working places at all hours day and night. There can be no difficulty at the coal face as the men can switch off and on as required, but there are difficulties in the cases of the main roads, lyes and shaft bottoms.

The object of these notes is to look into various ways and means of avoiding wasteful expense if ever the lighting of mines complete and all through has to be done. The author believes that the system of wiring shewn on the diagram, Fig. 1, if followed out in mines when required, would save a very large sum of money annually and at the same time would fulfil all the requirements of the law in having the mines well lighted from end to end. The workmen as they pass along would switch off the section just passed through and switch on the section they are entering into. By this system of wiring the workmen could have a well lighted road all the way.

The system proposed may be a little more difficult to fit up and cost a little more money (first cost) but the amount of money saved would soon compensate for that, and in the end there would be a great saving annually.

The diagram, Fig. 1, clearly shews what is meant by single and intermediate switches being used. It may be said that if two men were in the same section, the one some distance in front of the other, when No. 1 reaches the end of the lighting section he would switch off and leave the section in darkness before man No. 2 was out. That might happen, but man No. 2 having the intermediate switch at his hand could switch on anywhere.

A glance at the diagram will shew that this system of wiring for lighting gives complete control from any point ; it will also be appreciated that there might be many hours in the 24 when the lights would not be burning. Shaft bottoms, lyes, and all side roads can be controlled in this way. It will also be seen that it is only when men are passing out and in roads that the lights are used, and even then it is only small sections of the roads that are lit up at a time by this control. The wiring is arranged so as to control the lights in groups. There is no difficulty in switching off and on for any workman. He never requires to stop, but just pushes switches off or on while passing. The convenience of such control will be apparent.

This system of wiring would suit any voltage, and be also suitable with "master switches," which could interlock the lighting in the off or on position, so that no movement of any of the other switches would put off or on the lights. The master switch would be under the control of a responsible person to operate it as and when required, and that would prevent persons tampering with the lights in any way. If ever lighting comes to be adopted all over underground the mining electrical men must be able to comply with such Regulations as will be enacted. It is very certain that with universal adequate lighting the miner and others will give a better output and cleaner coal. Moreover, better lighting would also prevent nystagmus, wich alone would repay all the trouble and outlay of the instalment. With these obvious great advantages in mind one is prompted to urge the question : why not adopt general illumination underground now ?

Discussion.

Mr. GARVEN said he had not had much experience of different forms of mines lighting, but he had had experience of 500 volts with 5 lamps in series, which he thought Mr. McPhail would say was not a good way. Possibly they should have trip switches in, so that should one lamp fail the current would be automatically switched off, but they had not got that. He was in a pit some time ago, where at every haulage and light they had a small transformer (a.c.) and he thought that was a good arrangement. There was a small transformer for lighting, and even a small transformer for signalling. With regard to the 500 volt series being somewhat dangerous, he remembered seeing a lamp being put in, without the current being cut off. He did not think there was any excuse for that. It was an arrangement for shewing when current was off on 500 volts. The name of the seam was opposite the lamps. The name was lit when the lights were on, and when the switch went out the lights went off. When a lamp was broken another was put in, but it shorted across the lamp caps, and the lamps went off with a bang. It was a lesson not to do that.

Mr. COLVIN said he wondered if a system of, say, 500 volts d.c. with neutral wire, would be a permissible system. It would obviate the series system of lamps.

Mr. McPHAIL said there was nothing in connection with it in the rules further than that when lamps were being changed the power should be cut off. In connection with d.c. on a pressure of 500 volts it was usual to take the power from the box to the first lamp, and then from there to the next lamp, and from that lamp back to the cable. That was what was called a series parallel circuit, practically two 250 volt lamps in series. The wire between the two lamps was at earth potential, but should a fault occur that wire might become live. The safest way when using lighting in series parallel was to bring both the lamps together in pairs and put them in parallel across the mains : the small length of wire between the lamps connected them together and the arrangement made a fair system of lighting at 500 volts.

Mr. HENDERSON said there was a question in one of the recent examination papers : what is the maximum permissible voltage drop in lighting cables ? What would be allowed in a system of 105 volts and 1500 watts ?

Mr. McPHAIL said that, so far as he knew, the maximum permissible voltage drop was not given, but in the case mentioned he thought it would not exceed 5 The cable might be of any length, but the longer it was the greater would its cross-sectional area have to be.

Mr. GARVEN said he was interested in that question because some years ago his Company had a pit to light up. It was half-a-mile from another pit, where there was a 110 volt d.c. dynamo. The question arose, should they carry the 110 volt cable from the one pit to the other and use the generator that was at the first pit, or should they put in a motor generator at the new pit? They decided in favour of the motor generator. They considered the voltage drop would be too great when all the lighting was on, and that there would be a considerable difference between the voltage with only a few lights on and with all the lights on.

Mr. DAVIES said that in the case of a colliery requiring flame-proof apparatus, sufficiently robust to withstand underground usage, to put in a number of intermediate switches would be a costly business. Also, there would have to be one particular person underground responsible for the duty of switching the lights, otherwise no one would be responsible. Would they make the fireman, haulage-man, or road-man responsible for that duty? A number of switches would tend to wastage of current on shifts other than actual working shifts.

Mr. McPHAIL said the boxes were small things and would not be expensive. It would be handy in cases where men, after switching on in passing, were perhaps not going the whole way: an intermediate switch would then be of use. For lighting, a very small box sufficed, and yet it could be flame-proof. The cable used should be of cab-tyre and four-core. If it was a three-phase circuit and neutral, they should arrange that the lights were balanced across the phases all the way. The cab-tyre cable was the best because it was easily workable at the coal face: it was practically impossible to manœuvre armoured cable at all.

Mr. MacCALLUM said the idea of lighting at the coal face had been discussed by the branch previously, on a letter from the Home Office. The proposal was that lamps should be installed along the face at 12 feet intervals; 12 volts at a gate-end box. It was discussed exhaustively and some thought it a good idea, and others thought it was not. There were many points to be considered in lighting a colliery. Why should they go to the expense of leading cables into a section that was only going to last a year or eighteen months?

Consideration would have to be given to the probable life of a section before deciding whether lighting would be a feasible economical proposition or not. He appreciated Mr. McPhail's views on the question of economy in lighting. Coming from Edinburgh recently he passed a colliery which was ablaze with lights, and not a single thing was being done in it. It struck him what a waste that was. It had to be borne in mind that the men would not be carrying lamps when this new system was adopted underground It was suggested that the general use of hand lamps would not be necessary.

Mr. COLVIN said his experience was that there was great difficulty in getting the current cut off at any time. If ever there was a repairing job to be done or they wanted the power shut off, someone was needing the power. If they had lights besides and they wanted the power cut off for some purpose, they would find the lights a further drawback. If they cut off the power the men would have to stop work because they would have no lighting. That appeared to him a serious drawback. He would not like to have to instal lights along a 14 inch seam. He had seen a 14 inch seam working fairly effectively with electrical appliances, but he thought that to add a lighting sytem would be too much.

Mr. DAVIES said he could not realise that anyone was anticipating a time when hand lamps would not be carried underground. In a colliery requiring flame-proof apparatus every man would still have to carry his safety lamp.

Mr. McPHAIL said that from what he had heard and read he thought that some system of lighting was coming, and if that were so it was well that they should be prepared to meet the problems that would arise. It was only by discussion at the branch meetings and elsewhere that they could arrive at the best solutions. The system he had tried to explain was primarily to assist the electrician in his work, in making joints and fitting up cables, so that there would be a minimum amount of danger and of expense in maintenance.

Mr. McGLASHAN said it seemed to him that one of the chief objections to Mr. McPhail's system was this: how were the men going to find the switches? They would almost require pilot lights to indicate the switches. It was all right in a house—on a staircase or in a room—one knew where to expect the switches, but the conditions were very different down a pit.

Mr. McPHAIL replied that the man down a pit would find the switches without difficulty—he had done so himself regularly.

KENT SUB-BRANCH.

The Utilisation of Low Pressure Steam in Turbines.

W. R. HOWARD.
(MEMBER).

(*Paper read 10th January, 1931*).

The practice of using the exhaust steam from colliery winding engines to generate power in turbines is very common, in fact, approximately 85% of the steam winders in use in this country exhaust into mixed-pressure turbines. Winding engines are not, generally, efficient users of steam. The reasons for this are of interest in connection with this paper and, although forming a large subject in themselves, it will be advantageous to deal with them briefly. The main reason in most cases is that the full expansive properties of the steam cannot be utilised, for if an engine be considered which is required to raise a heavy load form a great depth, it is found, if the cylinders be designed to use the steam expansively to the extent possible when working in conjunction with a condenser, they would be far too large for practical considerations. Also the extra cost of the massive parts required is not justified by the saving obtained in steam, because allowance must be made for depreciation in value of the plant and interest on the extra capital involved, before reckoning the saving in steam.

Even in the case of a non-condensing engine it does not pay to expand the steam to the full extent possible throughout the whole wind, for when consideration is made of the variation in load during each wind, it is found that the engine which is most economical in overall cost (i.e. initial cost plus running cost) allows very little expansion of the steam during the first part of the wind. During this period the engine has to accelerate the drum, cages, tubs, rope, etc., and the point of cut-off would probably be as late as 90% of the stroke, but when the maximum speed is attained the cut-off can be earlier, and the engine will then use the steam more efficiently.

From the foregoing it will be seen that only winders for light duty can expand the steam to the pressure in the condenser.

The majority of winding engines eject large quantities of steam containing a considerable amount of available heat energy, especially during the early part of each wind, however, when the exhaust steam is taken to a turbine the available energy can be made to do useful work at a reasonable cost. So it is found that although the steam winder may be described as an inefficient user of steam, the combination of a steam winder and low-pressure turbine forms quite an efficient installation.

The following data will demonstrate the quantity of energy which is left in the steam as it leaves the winder. Consider a simple duplex winding engine having cylinders 36 inches in diameter and a stroke of 72 inches, which is quite an average size for a modern winder, the steam consumption of such a winder when using steam at 175 pounds per square inch absolute pressure, and exhausting against a back pressure of 18 pounds per square inch (absolute), would be approximately 35,000 pounds of steam per hour, and the work done by this steam in the engine cylinders would be about 110,000 foot-pounds per pound of steam. If the exhaust steam is used in a turbine working with a final pressure of 1 pound per square inch (absolute) the work done by the steam in the turbine would be approximately 122,000 foot-pounds per pound of steam. In this instance the steam actually does more work in the turbine than in the winder, and this is often found to be the case. After allowing for losses in the turbine and alternator, approximately 34 pounds of exhaust steam would be required per kilowatt-hour delivered at the alternator terminals; so it is found that, under the conditions quoted, the steam rejected per hour from the winder is capable of generating 1030 kilowatt-hours.

Having observed that there is a large quantity of available energy in the exhaust steam, there still remains the question of cost involved to utilise this energy. It has already been stated that the cost of adopting a winder large enough to expand steam to a low pressure is prohibitive, but it is found that using the turbine for this purpose is quite an economic proposition, and the reason for this lies in the adaptability of the turbine to use steam at velocities very much higher than are possible in a reciprocating engine the size of turbine required to deal with large quantities of steam is, therefore, comparatively small.

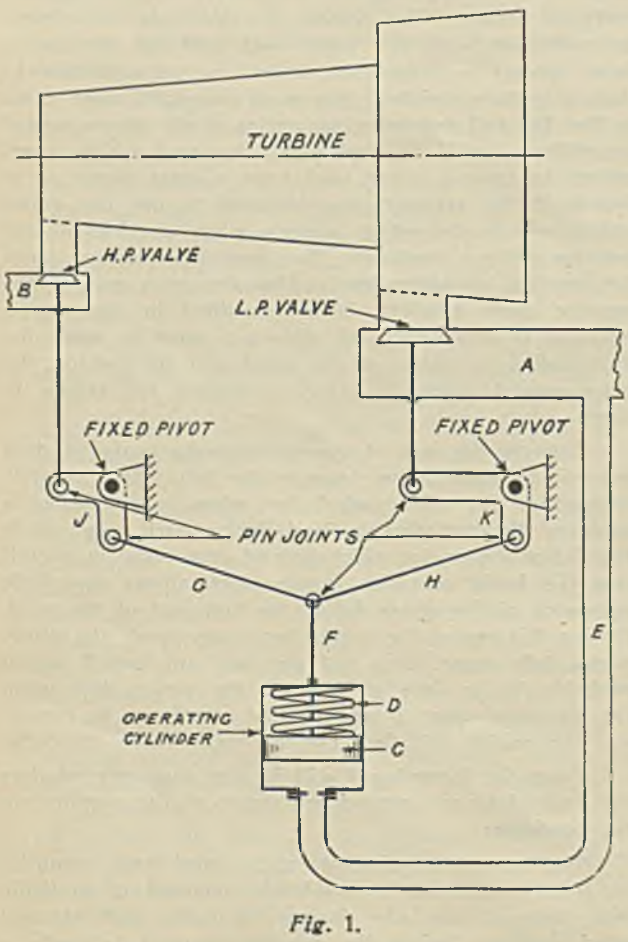


Fig. 1.

The economy of turbines in the use of low-pressure steam is well-known, but to make this point clear, consider a turbine expanding steam from 175 pounds per square inch (absolute) to 1 pound per square inch (absolute), then it is found that 50% of the work is done during the pressure-drop from 175 pounds to 20 pounds per square inch (absolute), and the remaining 50% is done during the pressure-drop from 20 pounds to 1 pound per square inch (absolute).

Either a simple low-pressure turbine or a mixed-pressure turbine may be adopted for utilising the low-pressure steam, but the mixed-pressure turbine is more adaptable in its application, and by far the most common in use.

The simple low-pressure turbine is dependent on the average quantity of low-pressure steam available for the maximum load which it can efficiently carry, in the event of a failure of the low-pressure supply it becomes necessary to introduce high-pressure steam (at the reduced pressure) into the low-pressure system and this is very inefficient.

The mixed-pressure turbine is a combination of a high-pressure machine and a low-pressure machine working within a common cylinder and on one spindle, the high-pressure steam is admitted at one end of the machine and passes through all the blading to the exhaust; the low-pressure steam is admitted at a stage where the high pressure steam has expanded to a corresponding pressure, the two then mix and pass forward through the low-pressure blading to the condenser.

The mixed-pressure turbine is designed on similar lines to a high-pressure machine except from the stage where the low-pressure steam is introduced to the condenser end, throughout this range the size of the machine is increased (out of proportion to the ordinary increase which provides for expansion) to accommodate the greater volume of low-pressure steam.

The maximum load which can be efficiently carried by the mixed-pressure machine is not controlled by the available quantity of low-pressure steam, because steam can be admitted at the high pressure end to make up for any shortage of low-pressure steam.

The illustrate the operation of the mixed-pressure turbine consider the machine to be working on high-pressure steam only, the high-pressure valve will be open and the low-pressure valve shut, when low-pressure steam becomes available an automatic change-over gear opens the low-pressure valve and closes the high-pressure valve by a proportionate amount. When the low-pressure supply diminishes, the reverse action occurs, i.e. the change-over gear reduces the inlet for low-pressure steam and increases the inlet for high-pressure steam. During the foregoing operations, if the change-over gear is correctly proportioned, the speed of the machine will remain constant both during and after the change-over, but if the gear is incorrectly proportioned the speed will fluctuate.

Figure 1 shews a diagrammatic arrangement of an automatic change-over gear for a mixed-pressure turbine, A, is the low-pressure main, and B the high-pressure main, the operation of the gear depends upon the low-pressure steam acting on a piston C, against the resistance of spring D in a cylinder, steam is supplied to this operating cylinder from the low-pressure main through pipe E. The method of operation is as follows, when the pressure in the low-pressure piping increases the piston C and its rod F are raised, this movement causes the two rods G and H to push the vertical arms of the two quadrant levers J and K outwards and away from each other, the quadrant levers are thereby rotated through a small angle about their fixed pivots, resulting in the horizontal arm of quadrant lever J being raised and moving the high-pressure valve towards its seat, while the horizontal arm of quadrant lever K is lowered thereby drawing the low-pressure valve away from its seat.

As the low-pressure steam operates the piston against the resistance of a spring, it is obvious that the amount of movement will depend upon the pressure available, i.e., the higher the pressure, the greater will be the opening of the low-pressure valve and the greater the closing of the high-pressure valve. This principle of operation is quite correct, the intensity of pressure is a direct indication of the quantity of steam available as will be seen later when considering the storage of steam.

It should be noticed that Figure 1 is only a diagram representing a principle involved and not a practical mechanism, the simplified mechanism shewn has been chosen to avoid any unnecessary complications. In actual practice the movement of the piston C only operates a relay gear which in turn introduces external forces to operate the valves. It is necessary that the low-pressure valve as well as the high-pressure valve be brought under the control of the governor, so that in the event of the low-pressure supply being in excees of that required to carry the load, there is no likelihood of the machine overspeeding. Both valves must also be under the control of an overspeed tripping gear. These additional appliances have been omitted from Figure 1 for reasons previously stated.

The most economical size of mixed-pressure or low-pressure turbine for any particular job is that which utilises the average quantity of low-pressure steam; but getting this steam supplied to the turbine at the average rate of flow presents difficulties, and these will now be considered.

The winding engine generally provides the largest quantity of low-pressure steam at the colliery, and this supply varies from nothing to a maximum during every wind. It is necessary, therefore, that a system of storage be adopted which will receive the excess team during the period of maximum supply and give out steam when the supply falls below the average.

There are three systems of storage in general use, the first of these consists of a simple metal receiver in which the pressure rises to the maximum permissible when the supply is excessive, and falls to the lowest permissible pressure during the periods of low supply. This is not a good system as the actual storage capacity is remarkably low, resulting in a large quantity of steam being wasted through the relief valve during the early part of each wind, and a rapid fall in pressure between winds, the reason for this will be shewn later.

In the second system a receiver of variable capacity is used which works on the same principle as the gas-holder, the sides and top are plated, the bottom being sealed by immersion in water. When the receiver has discharged its steam it is nearly full of water, and when the receiver is charged with steam the greater portion is out of the water, but a sufficient depth must be kept under water to provide a seal. Between the limits of the receiver's movement the steam is stored at constant pressure, any surplus steam simply raising the tank further out of the water, at the top limit of travel the steam is stored at increasing pressure until the highest permissible pressure is reached, at this pressure any surplus steam is blown off through a relief valve. When the receiver is discharging and falls to the lowest limit of its travel the pressure will continue falling until the lowest permissible pressure is reached, at this point the demand for low-pressure steam at the turbine ceases, so there is no danger of the water being drawn into the turbine. This system is better than the first mentioned, but a large receiver is necessary to give ample storage.

The third system consists of a heat-accumulator, the general principle involved being the condensation of steam in a tank containing water during the periods of surplus steam, and the regeneration of some of the water to steam during the periods when the supply of steam is low. This is the most efficient system for quantity of steam stored compared with the size of storage plant, and the cheapest for the results obtained.

Figure 2 shews a typical heat-accumulator, consisting of a cylindrical steel shell with a central perforated tube, the accumulator contains water to the level shewn. Exhaust steam from the winders etc. is fed into the central tube and passes through this tube into the water. If the demand of the turbine is just equal to the steam being exhausted by the winders etc., then the amount of steam leaving the surface of the water will just equal the steam being supplied to the accumulator. The level of the water will, therefore, remain steady and the water will be at the same temperature as the steam. Consider next that the supply to the accumulator becomes greater than the demand at the turbine, then the pressure in the pipes and accumulator will increase, and since the temperature of steam increases with the pressure, the temperature of the water in contact with the steam will also be increased, this increase in temperature of the water is due to some of the steam being condensed and giving out its latent heat. This process goes on until the highest permissible pressure is reached, after which any surplus steam escapes through the relief valve. When the supply from the winders etc. is less than the demand at the turbine, the reverse action takes place, the pressure falls and the temperature of the water is reduced thereby liberating heat which evaporates some of the water into steam. It is necessary to have a sufficient area of water exposed to allow for free evaporation during this falling pressure period, and for this reason the accumulator is only a little over half full of water. As heat losses due to radiation etc. are constantly occurring with consequent condensation of steam, the water in the accumulator will steadily rise, and to keep this down to the correct level it becomes necessary to drain off some of the water periodically or to instal a float controlled drain valve. A gauge glass which indicates the level of the water in the accumulator is shewn in Figure 2. Old Lancashire or Cornish type boilers are often used for this system of storage, the flues are perforated and the ends blanked, the exhaust steam is fed into the flues in a similar manner to that shewn in Figure 2.

This latter method of storing steam, which has been in use for this class of work for many years has, during the past few years come into prominence for the storage of high-pressure steam as a means of reducing the peak demands on boilers.

A comparison of the relative values of these three storage systems will now be demonstrated, and for this purpose consider a cylindrical vessel of 10 feet diameter

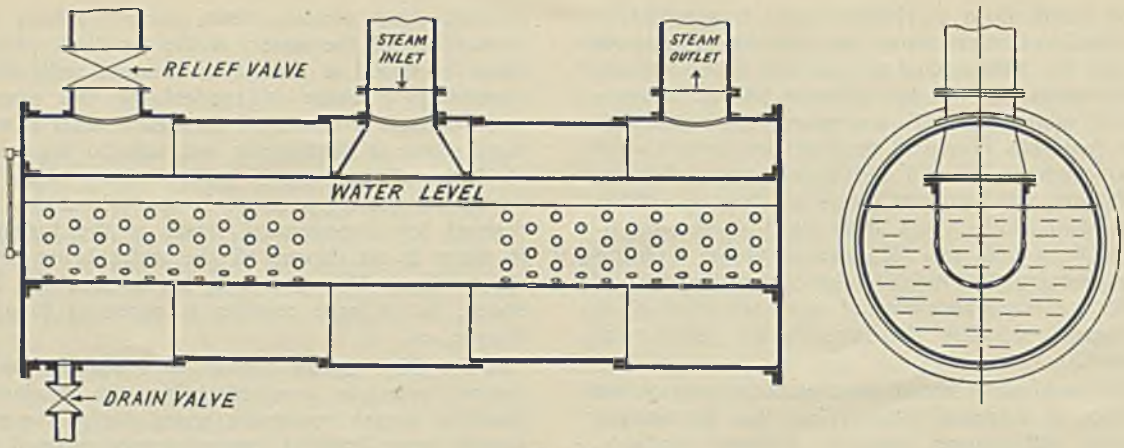


Fig. 2.

and 30 feet long in each case, let the maximum permissible pressure be 20 pounds per square inch (absolute) and the minimum permissible pressure 16 pounds per square inch (absolute).

The volume of the receiver is 2356 cubic feet.

In the first case the storage of steam is dependent only on the difference in density between the highest and lowest pressures, it is found from steam tables that the quantity of steam in the receiver at the higher pressure is 117.3 pounds and the quantity contained at the lower pressure is 95.2 pounds, so the effective amount of steam stored is only 22.1 pounds, this is a very small amount and shows how futile it is to attempt the storage of steam in this manner.

In the second case it is assumed that the whole volume of the receiver is discharged and that the discharge takes place at the mean pressure of 18 pounds per square inch (absolute). If, at the commencement, the receiver is full of steam at 20 pounds pressure there will be an initial discharge of 11 pounds of steam while the pressure is falling from 20 to 18 pounds, this will be followed by the discharge of the whole volume of the receiver (i.e. 2356 cubic feet) at a pressure of 18 pounds per square inch (absolute); this constitutes 106.3 pounds of steam, so that the total effective storage capacity of the receiver is 11 + 106.3 = 117.3 pounds; which is considerably greater than the first type.

To arrive at the storage capacity of the third system, it is necessary to calculate the total heat in the accumulator when fully charged and the heat left in the accumulator when discharged. It has been demonstrated that the storage in the steam space is almost negligible, therefore, in the following calculations the storage in the steam space will be omitted and only the storage in the water considered.

The weight of water in the receiver when filled to the level shewn in Figure 2 is 88,000 pounds.

The following data is abstracted from tables of properties of saturated steam:—

Absolute pressure in pounds per square inch.	Temperature, or boiling point in deg. F.	Total heat in water from 32° F. in B.Th.U. per pound.	Total heat in steam from 32° F. in B.Th.U. per pound.
16	216.3	184.4	1152.0
18	222.4	190.5	1154.2
20	228.0	196.1	1156.2

When the accumulator is fully charged at a pressure of 20 pounds per square inch (absolute) the total heat in the water will be 88,000 × 196.1 = 17,256,800 B.Th.U.'s.

Let W pounds of steam at an average pressure of 18 pounds per square inch (absolute) be evaporated during the period of falling pressure, then the total heat in this steam will be (W × 1154.2) B.Th.U.'s.

At the end of the discharging period when the pressure has fallen to 16 pounds the accumulator will contain (88,000 — W) pounds of water, and the total heat left in this water will be

(88,000 — W) × 184.4 B.Th.U.'s.

The foregoing statements are embodied in the following equation:—

$$\left\{\begin{array}{l}\text{Heat in water at}\\ \text{commencement of}\\ \text{discharge period}\end{array}\right\} - \left\{\begin{array}{l}\text{Heat in water at}\\ \text{the end of}\\ \text{discharge period}\end{array}\right\} = \left\{\begin{array}{l}\text{Heat in}\\ \text{W. pounds}\\ \text{of steam}\end{array}\right\}$$

$$17{,}256{,}800 - (88{,}000 - W)\ 184.4 = 1154.2\,W.$$
$$17{,}256{,}800 - 16{,}227{,}200 + 184.4\,W = 1154.2\,W.$$
$$1{,}029{,}600 = 969.8\,W.$$
$$W = 1062 \text{ pounds.}$$

Therefore, the theoretical effective storage capacity of this accumulator is 1062 pounds of steam, and the superiority of this type over the others is obvious. This figure is not generally attained in practice owing to the difficulty of sufficiently distributing the steam in such a large bulk of water as to raise the temperature of the whole quantity: but, in a well-designed accumulator, a large proportion of the calculated amount can be obtained.

Some of the difficulties which present themselves in connection with low-pressure steam systems of the types under consideration will now be discussed.

When large receivers or accumulators (other than those of the gas-holder type) are shut off, it is possible for a cold atmosphere to condense the entrapped steam and create a vacuum; then a receiver, which was designed for internal pressure, is subjected to external pressure and collapse of the casing under these conditions is very probable. To prevent this condition arising a small valve can be fitted, this valve is held in the closed position when the internal pressure exceeds the external but opens and admits air when the internal pressure falls below that of the atmosphere.

When it is known that a large quantity of air has been admitted to the receiver precautions should be taken to admit the low-pressure steam to the turbine at a low rate of flow until the air has been cleared out of the system; otherwise, there is a possibility of the air extraction plant being overloaded, resulting in a loss of vacuum in the condenser.

If the low-pressure valve at the turbine is not perfectly tight, there is a possibility that the pull of the condenser may draw air into the low-pressure system during the periods when the winders are standing. To prevent this occurrence it is advisable to have a regular supply of low-pressure steam, such as the exhaust from a fan engine or compressor, in addition to the fluctuating supply from the winders, so that a pressure is maintained in the system at all times.

The pulsating action of the exhaust from the winding engine is generally noticeable throughout the whole system, and may be pronounced enough to have a detrimental effect on the turbine automatic change-over gear by setting up a periodic swing: this swing is caused by the impulses being imparted to the piston in the operating cylinder. The use of large receivers and large mains are advisable as a means of combating this trouble, but are not generally sufficient in themselves to effect a cure. The trouble can be overcome by fitting at the inlet to the operating cylinder a diaphragm plate having only a small hole for the admission of steam, the pulsations inside the cylinder are thereby damped out owing to the time required for any change of pressure in the mains to be registered in the cylinder. A diaphragm for this purpose is shewn in Figure 1. The velocity of the steam at the inlet to the turbine becomes so high as the steam is expanded, that the impulses die out, and there is no detrimental effect at this point.

The steam leaving the winding engine carries along oil in suspension, this must be separated out and trapped before it reaches the turbine, otherwise the baffling effect of the blades separates the oil, resulting in choking of the steam passages. The oil separator generally consists of a series of baffles on which the steam impinges and deposits the particles of oil: as the oil accumulates it trickles down the baffles and is guided by them to the bottom of the separator, where, along with any water present it is discharged through a steam trap. The mixture is then led to a small tank where the oil floating on the water can be drawn off and used for low-grade work.

The low-pressure steam also carries with it a quantity of moisture: the steam main should, therefore, be well equipped with traps to catch and discharge the water before it reaches the turbine. If it can be arranged, the steam main should rise from the accumulator to the turbine, so that water tends to run back to the accumulator. It is also advisable to cover the piping and accumulator with non-conducting material to avoid heat losses and prevent condensation.

NORTH OF ENGLAND BRANCH.

Lecture by Mr. Sydney Burns.

The fourth meeting of the session of the North of England Branch was held on January 16th last, at Neville Hall, Newcastle. An interesting lecture was given by Mr. Sydney Burns, the Branch Vice-President.

The title of Mr. Burns' lecture was "Better Days—Better Ways," and the mining methods of the last 100 years were described and illustrated by lantern slides. The lecturer contrasted the old time conditions and the long hours spent below ground with the modern mining methods. More than fifty members and visitors were present and a very hearty vote of thanks was accorded to Mr. Burns for his able and instructive lecture.

Dinner and Smoking Concert.

A very successful social evening was held by the North of England Branch at the County Hotel, Newcastle, on Saturday evening, February 13th last. Apologies for absence were received from Maj. E. Ivor David, President of the Association, Mr. Sydney Bates, Branch President, and from other members and friends who were unavoidably prevented from being present. The Dinner was attended by 107 members and guests and was followed by a smoking concert. In the absence of the Branch President, the Branch Vice-President (Mr. Sydney Burns), took the chair and was accorded a hearty vote of thanks for his services during the evening.

NORTH WESTERN BRANCH.

Annual General Meeting.

The annual general meeting of this Branch was held on Friday, March 18th, 1932, in the rooms of the Manchester Geological and Mining Society, Manchester. Mr. S. J. Roseblade presided over an unusually large attendance which included Mr. Horsley, Chief Electrical Inspector of Mines.

The following were elected to membership. Members: Mr. Edmund McLaren Keay, Colmore Row, Birmingham, salesman electrical engineer; Mr. Eric Dobb, Birkdale, Southport, test engineer; Mr. John Smith, Beech Hill, Wigan, engineer in charge; Mr. Wm. Williams, Wrexham, electrician in charge; Mr. Albert Bishop, Walton Hall, near Sheffield, electrical engineer. Associate Members: Mr. James Wilcock, New Springs, Wigan electrical draughtsman; Mr. Fredk. Richdale Hill, Shevington, Wigan, colliery electrician; Mr. Denis Rathbone Winstanley, Congleton, Cheshire, colliery electrical engineer; Mr. George Albert Shenton, Stoke-on-Trent, colliery electrician; Mr. Richard Aspinall, Wigan Lower Road, Wigan, colliery electrician.

The following are the officials for the ensuing year.
President—Mr. S. J. Roseblade.
First Vice-President—Mr. J. Whittaker.
Second Vice-President—Mr. F. H. Williamson.
Treasurer—Mr. W. Bolton Shaw.
Auditors—Messrs. Bowman and Henshaw.

There were two nominations for one vacancy on the Committee and on a ballot Mr. G. Pearn was elected.

THE PRESIDENT remarked that it was perhaps desirable that some explanation should be offered for the officers being the same as last year. Mr. Whittaker, who was elected First Vice-President, last year should, in the normal course, have become President, but for business reasons he would prefer to take the position next year. The Committee considered the matter and suggested that in the circumstances the retiring officials should remain in office.

The following was then read by Mr. H. Rainford, D.F.H., A.M.I.E.E., A.M.I.Min.E.

Design and Maintenance of Flame-proof Enclosures for Mining Electrical Apparatus.

H. RAINFORD.

The use of electrical apparatus underground introduces a risk of ignition of firedamp and in combating this danger the main safeguard must always be adequate ventilation. There is however a second line of defence in the safeguarding of the electrical apparatus itself in order to minimise the risk of "open sparking." This safeguard is obtained by flame-proof enclosure and the object of such an enclosure is to prevent the ignition of a surrounding explosive atmosphere either (a) directly from electric arcing or sparking within the enclosure, or (b) indirectly from the ignition of an explosive atmosphere therein, whether introduced from outside or produced within the enclosure.

With regard to classification (a), it is necessary to draw attention to the definition of flame-proof enclosure as outlined in B.S.S. 229. This definition makes it perfectly clear that the flame-proof quality of the enclosures is limited to conditions of operation within the rating of the apparatus, and the protection of the circuit must be such as to ensure, as far as practicable, that the highest recognised overloads for the apparatus shall not be exceeded.

With regard to classification (b), it follows that an ignition of gas must be confined to the interior of the enclosure.

It is generally known that the limitation of combustion to the interior of a flame safety lamp is brought about by Davy's principle of "cooling" and this principle finds application in the use of electrical apparatus, where the essential parts are enclosed in flame-proof containers. The requirements of these flame-proof enclosures, however, are not satisfied by contrivances quite so simple as those employed for flame lamps owing to the comparatively high pressures developed within the enclosures.

In this respect, note that the term "flame-proof" is synonymous with "explosion proof," that is to say, a casing must be able to withstand, without injury, the force of an explosion within it and must prevent the transmission of flame to the exterior.

The precautions to be taken in connection with flame-proof enclosure may be considered under two headings, design and maintenance, the one being mainly the concern of designers and manufacturers and the other the concern of those responsible for the installation, operation and examination of the apparatus.

With regard to design, the following notes deal with general considerations, since it is not possible to cover different classes of gear, with their varying types of fittings, at one sitting.

Consider then, a simple structure consisting of a casing and one or more covers. The first detail that requires attention is the size and shape of the enclosure. Both the size and shape must of course be dependent on the type and amount of the gear to be enclosed, and the point to be stressed here is that the amount of air space—which is the gas space from the present point of view—should be kept as small as possible.

The larger the amount of explosive mixture which can be trapped within the enclosure, the more violent is the explosion to be anticipated if the explosive mixture is ignited.

It is not possible to forecast, with any accuracy, the cooling effect of the metal—comprising the electrical gear enclosed and the walls of the casing—on the resulting flame and gaseous products, and it is necessary to concentrate on keeping the amount of air space small, relative to the size of the enclosure.

Comparatively high pressures may be produced in quite small enclosures, for example, in slipring enclosures, the shape of which often approximates closely to a sphere and in which the internal gear is concentrated at the centre.

The latter point leads to consideration of the disposition of apparatus within a container. The generator of pressure is a gaseous explosion is the flame-surface which moves through the explosive mixture. Variations in the motion of this surface, as caused by the position of the internal gear relative to the ignition point, are reflected in the production of pressure.

One essential point arising from this is that the layout of the gear, including such items as insulating partitions, should be such that the air space is not compartmented. Otherwise flame started in one part of the enclosure may project into the other an incentive jet, which will cause the simultaneous ignition of a large portion of the remaining explosive mixture, with a consequent higher rate of rise of pressure than if the flame spread evenly through the container.

When it is desired that several component units of control gear shall be placed within one container, it should be noted that the scheme, although undoubtedly convenient electrically, introduces difficulties with respect to flame-proof enclosure. A large amount of free space is generally unavoidable in these instances and there may be a large area of cover unsupported except round the edges where the cover is bolted to the casing. The suggestion here is that the casing should be divided on the bulkhead principle each section of the gear being isolated by the dividing walls which can be fitted with flanges as additional support to the cover which closes the container as a whole.

As to the material to be used for constructing the enclosure, this is generally a question of castings versus steel plate. The impact effect of an explosion pressure on a brittle structure cannot be neglected and it is desirable that the use of cast iron should be limited to comparatively small structures, the walls of which can be made relatively thick. The main difficulty with cast iron is that, even though a sample enclosure may pass an explosion test, manufacture in bulk is liable to uncontrollable variations. There is also the risk of fracture under colliery conditions of use and this risk should not be overlooked when the size of the enclosure is considerable and the section thin. On the other hand light fabricated structures must be looked upon with a certain amount of suspicion but this point can perhaps be left with the hope that "tin kettles" are a thing of the past so far as mining electrical plant is concerned.

Diverting to one particular type of apparatus, namely oil-immersed apparatus, it is now generally recognised that oil immersion, while assisting to add greatly to electrical efficiency and limitations of size, introduces its own danger. This danger is the liberation of inflammable gases as a result of the arcing at the contacts under the oil. The gas produced in this way consists mainly of hydrogen and for this reason hydrogen is now used for the internal explosions in the standard test for flame-proofness on casings for oil-immersed gear.

The main concern is that the rate of development of pressure with hydrogen is much faster than with methane, and brittle structures may be unable to withstand this condition. For oil tanks, therefore, it is to be expected that the construction shall be of welded steel plate, and this quite apart from considerations of rupturing capacity.

The next point is the attachment of covers and fittings, which opens up the question of external flanges versus internal flanges. Internal flanges may make a more compact job but that is all that can be said for them, unless precautions are taken to prevent the presence of holes through the casing.

Reference to Mr. Horsley's annual reports over a number of recent years reveals that in a number of instances ignitions of firedamp external to electrical apparatus have been caused by containers rendered non-flame-proof by the omission of bolts or screws from holes which penetrated into the interior of the containers.

In general, the solution lies in the provision of external flanges whereby the bolts are kept clear of the walls of the casing. It is, however, recognised that internal flanges are not always avoidable—a particular instance being the attachment of fittings to the walls of steel plate casings—and the designer should therefore make the provision of "bottomed" holes a first consideration.

With castings it is not a very difficult matter for bosses to be cast on the underside of the flanges thus giving a sufficient depth of metal for bottomed holes. Similarly bars or blocks of metal might be welded to the walls of casings built up of steel plate.

The use of studs, riveted or welded to the casing, should not be regarded as an easy alternative. Should a stud be damaged while the apparatus is in use, it may or may not be replaced and if it is replaced it is conceivable that the necessary riveting or welding will be postponed to a more convenient time, and subsequently overlooked.

The size and number of bolts used to secure covers and fittings will vary with size and shape of an enclosure, but these details, coupled with quality, must not be overlooked since they may prove to be the weakest link in the designed strength of the enclosure as a whole. An additional point here is that the bolts may not be equally loaded in practice.

The establishment of electrical connections between the interior mechanism of a flame-proof unit and the supply cable is a feature of design which requires special attention. The method of direct entry which involves taking the cable directly into the casing, through stuffing boxes or glands attached to the wall, is now superseded. This method of cable attachment may be safe as designed but reliance has to be placed upon correct installation and maintenance. The method to be used, therefore, is the indirect method whereby the supply cable is connected within a terminal box external to the main enclosure. Connection between terminal box and the main enclosure is effected by means of insulated terminal stems projecting through the dividing wall.

The design of the terminal box depends mainly on the terminals to be enclosed and the type of cable fitting to be used, but it is desirable that the terminal box should have a flame-proof cover joint so that with the intelligent co-operation of the user—who is responsible for the attachment of the cable—the terminal box shall constitute a flame-proof enclosure.

If a plug and socket coupling is used for connecting a cable to the main flame-proof enclosure then the base of the coupling must seal the cable aperture in a flame-proof manner and the construction of the contact moulding must be such that the contacts form the equivalent of the insulated terminal stems previously referred to.

With regard to interlocks, it can be said that they do not form an essential feature of flame-proof design. They are in fact primarily a precaution against shock, but they do form a guard against the operation of apparatus when incorrectly assembled and as such they must remain intimately connected with the flame-proof enclosure with which they are used. Similarly, the arrangements for securing all covers which are frequently removed for purposes of inspection or repair should be designed so as to guard against unauthorised removal.

Thus far, no reference has been made to specific dimensions and this omission has been deliberate, on the grounds that the design of flame-proof enclosures involves something more than mere compliance with a list of dimensions.

It is necessary, however, to refer to limits and the minimum acceptable dimensions for the breadth of joints and similar passages between rigid flanges, bearings etc., is one inch. In many instances it is necessary to increase this dimension in order to obtain greater rigidity and to provide a sufficient breadth of flange surface for the size of bolt to be used.

The width of the gap or opening across the passage is limited to 0.020 inch and this limit should be adhered to whatever may be the length of path, for the reason that the cross-sectional area of the opening is, within these limits, of more importance than the length of path.

Note that the maximum dimension of 0.020 inch for width of gap refers only to coal mining and the relatively inert gas firedamp. When other more explosive gases or vapours have to be considered, the width of gap has to be considerably reduced in order to ensure safety.

Note also that the provision of gaps at passages other than bearings is not an essential feature of flame-proof design. In a large majority of instances sufficient release of pressure is obtained through joints with rough machined surfaces—or even with smooth machined surfaces—to prevent the pressure, resulting from an internal explosion, from reaching a figure which will stress the material to yield point.

Such release of pressure should however be considered merely as providing a small margin of safety against bursting or distortion and the aim of the designer should be to make the casing of sufficient strength to withstand the anticipated maximum pressure, plus a safety factor to cover variables such as the material used, without placing reliance on the release of pressure through joints and bearings.

If these points, together with the earlier points raised in connection with the size and shape of the enclosure and the layout of the internal gear, are kept in mind then it will be seen that the need for deliberate venting of a flame-proof enclosure should only arise in special and comparatively few instances.

As a final note on design, it is hoped that sufficient has been said to shew that the design of a flame-proof enclosure is not merely a matter of adapting an ordinary industrial structure but that a high and exclusive standard for these enclosures must be set and adhered to.

It is not intended to include in this paper details of the testing of flame-proof enclosures, but if time permits a brief outline of the provision made for this work will be given later with the aid of a few lantern slides which the author is able to exhibit by the courtesy of the Mines Department. Most of the members present have read Mr. Horsley's paper, on the testing work, which appeared in the January number of *The Mining Electrical Engineer*, and know that the tests are now carried out at the Mines Department Testing Station at Harpur Hill, Buxton.

Turning now to the question of maintenance of flame-proof enclosure in the pit, it will be obvious that those responsible for the operation and examination of the enclosures should be familiar with the essential features of design and the particular defects which constitute danger.

The best method of putting these items forward appears to be in the form of personal notes and, since the main object of these notes is to preach the gospel, the text can conveniently be "Have I done the things which I ought not to have done and have I left undone the things which I ought to have done."

In dealing with the question of maintenance it must not be overlooked that a certain proportion of the electrical gear in use was installed before the special requirements for flame-proof enclosure were fully appreciated and the correct maintenance of this older type of gear requires even closer attention than that given to gear of more recent design.

In this connection it is difficult to find a dividing line and consequently these notes deal as fully as possible with all types and designs that may be in use. Some of the details may appear trivial but they are none the less important. It is the minor detail which is frequently overlooked.

Examine the casings frequently to ensure that a cracked cast iron casing or a distorted steel plate casing is not being kept in use. Keep a similar guard against cracked or broken cast iron covers and bent steel plate covers.

Make sure that no bolts or studs are missing and that all nuts are tight. A missing bolt, stud or nut may result in the cover or fitting being insecurely attached, which is a likely cause of danger.

If, when a bolt or screw is removed, it is found that there is a hole right through the wall of the casing, replace the bolt or screw without fail and make sure that it is tight. If such a "through" hole in a casing without a bolt in it is found, get a spare bolt and fit it at once. Quite a number of ignitions of firedamp have been traced to unsealed holes of this kind. The same safeguard applies also to screwed plugs used to seal inspection holes or oil draining passages.

Where bolts are fitted into tapped holes in bosses, see that the bottoms of the holes are kept clear of dirt. Failure to do this may result in the bolts appearing to be screwed in tightly whereas they have come up against the dirt in the hole and they may not be gripping the cover or fitting which they are intended to secure.

On some enclosures it will be found that flange surfaces are spaced apart to provide vent gaps which will allow release of pressure in the event of an internal explosion. See that these gaps are not choked, and if it is necessary to clean them do not make the gaps any larger or they may become unsafe. Bear in mind what has already been said about the limiting maximum width of gap—it is 0.020 inch—and do not think that, because a gap is provided, a little more gap won't do any harm.

Where cables enter an enclosure through glands, make sure that the gland is properly packed and screwed in tightly. Do not fit a cable that is too small for the gland, even for a temporary connection. Passages through cable glands of this type are just as dangerous as the bolt holes previously referred to.

On most of the flame-proof enclosures it will be found that the cables are not taken direct into the main enclosure but that terminal stems are fitted in the wall of the casing, the outer ends of these terminals being covered by an auxiliary box within which the external cable is connected. Keep the terminals free from coal dust and moisture, and see that the cable gland is correctly fitted to the terminal box.

With oil-immersed gear, see that the oil is kept at the indicated level and that the apparatus is mounted correctly on its stand or bracket. Do not look upon the oil as the only safeguard against "open sparking"; the enclosure should be a flame-proof enclosure the same as for air-break gear.

Interlocks, electrical and mechanical, are provided as part of the flame-proof design and also to provide safety against shock. Do not look upon these interlocks as a nuisance; give them fair usage and see that they are kept in working order. A padlock may be provided (perhaps to lock a plug or a cover on to the apparatus) and it is necessary to see that the padlock is kept in use—on the apparatus.

The operation of the apparatus may in some way or another affect the flame-proof enclosure: to give one instance, a chain on a coalcutter worked off its guide wheels and cut a hole through the wall of the enclosure, a circumstance which led to an explosion. Such operating defects should be carefully guarded against.

Repairs in the working places should only be considered as a temporary measure and the electrical gear, particularly coal face machinery, should be periodically brought out for examination if the enclosures are to be kept in a safe condition.

Finally, the man should bear in mind that he is credited with a certain amount of enterprise and should take every opportunity offered to him for learning how to avoid danger. Confidence in himself and in the apparatus in use is dependent on knowledge. It is hoped that these notes will be of some assistance with respect to intelligent maintenance of the flame-proof enclosures of mining electrical apparatus.

Discussion.

Mr. J. A. B. HORSLEY (H.M. Electrical Inspector of Mines) said he had come to Manchester to join in the discussion because he had given continuous and close attention to the "flame-proof" problem ever since his appointment as H.M. Electrical Inspector of Mines in 1919. As a matter of fact he contributed a paper upon the subject of flame tight enclosure to the proceedings of the London branch of the Association in 1920.

The problem of constructing flame-proof enclosures for electrical apparatus which will be safe for use in coal mines is essentially an engineering problem, and it has been recognised as such by those manufacturers who have had intimate and long—one might almost say "bitter"—experience of coal face conditions. This led straight to the question of strength of structure and the use, or abuse, of venting and pressure relieving devices.

When the Mines Department—Mr. Horsley was speaking as the Official responsible for the general direction of this work—undertook to test and certify electrical apparatus as flame-proof, they accepted a serious obligation with a direct bearing upon safety in coal mines.

The Mines Department do not issue their certificates solely upon the ability of the model to pass tests with inflammable gas for they could not divest themselves of concern for the real safety of the design, i.e., its safety under working conditions. The Department must have some reasonable assurance that there is a sufficient margin of strength in all that pertains to the flame-proof enclosure over and above that which, perhaps barely, suffices to withstand the explosion of the appropriate inflammable gas. They must also be reasonably sure that those features of the design upon which the safety of the structure depends are likely to be repeated with the necessary exactitude in commercial production, and that they are of such a nature that they are not likely to become deranged, or to depreciate in use, under working conditions.

Venting devices offer a means whereby the strength of the structure may be reduced. If the vent area is sufficient there will be little if any measureable pressure developed, so that flame-proof enclosure can be attained without regard for strength.

Vents, therefore, are to be regarded with suspicion at the outset because they can be used at the expense of real safety. An exaggerated view of the influence of venting devices upon the pressure developed may be taken, if the cooling effect of the contents and of the walls of the enclosure, in actual apparatus, is not taken into account.

In actual apparatus, the inflammation of the enclosed gas is not completed before some part of the products of combustion are cooled by contact with the contents and with some part of the walls of the enclosure, and (in fact) it is sometimes found that the pressure is not seriously increased, where venting by spaced flanges is relied on, when the vent is closed.

On the other hand, it has been found sometimes that the margin between safety and danger is so narrow, in the matter of strength, that a moderate increase in pressure,—due either to closing a vent or to using a gas giving a somewhat greater pressure, such as substituting pentane for firedamp—results in deformation or actual destruction of the enclosure.

If, therefore, safety depends upon maintaining the vent opening so that it shall be neither too wide nor too narrow, it is necessary to be hypercritical when considering the design of that vent.

Is the gap likely to be repeated with the necessary precision, or, on the other hand, is it liable to vary from causes outside the control of the manufacturer?

Quite recently one of the assistants of the Department came across a venting device of the ring relief pattern, where the spaces were completely closed by hard rust. Where then was the safety valve? The condition of this particular device could be seen but, close by, there were others of the same general type but covered with a hood, so that the condition could not be seen. Furthermore, if the rings can be seen they can also be interfered with, so it is, at best, a choice of evils.

Mr. Horsley said he himself was certainly not willing to risk a colliery explosion for the sake of a little extra cost on a stronger housing. Acceptance of venting without regard for strength of structure would be to put a premium upon flimsy enclosures with the ultimate result of driving out of the market those designs that have been evolved as a result of first hand knowledge of the practical conditions of coal mining.

The present difficulty is to determine what the margin of safety ought to be, and how it shall be proved. It is simple to call for hydraulic test for cast iron structures of moderate dimensions for, unless they are manifestly unfit for colliery conditions, they will easily withstand twice the gas explosion pressure.

A "fabricated" structure, however, i.e., one built of welded steel plate, may in fact be much stronger and in other ways preferable but, owing to the elasticity of the material, the structure maybe would be deformed permanently by a sustained hydraulic pressure substantially less than that which a cast iron vessel would withstand.

The solution would appear to lie in specifying minimum scantlings with adequate bracing of the structure, but one does not want to interfere any more than is absolutely necessary with the individual designer.

There was just one other aspect of flame-proof enclosure which Mr. Horsley wished to mention. The explosions of firedamp due to electricity, happily few in number, are more often due to openings in the enclosure that would not have been there if the user had played his part in securing safety. Doors and cover plates that are fixed by numerous screws will always be a source of risk and Mr. Horsley could see no final remedy so long as that type of closure is used.

If, however, one could introduce the principle of the circular spigotted cover, a foolproof enclosure would be in sight. Consider this suggestion with respect to a switch: if the whole interior were attached to, and came away with, a circular spigotted cover, there being no other potential opening, it would be comparatively simple to devise an interlock that would compel the user to close the door before the switch could be used. This might involve the use of pin and tube or other sliding contacts to connect the switch terminals to the circuit inside the enclosure, but that need not present any insuperable difficulty.

Mr. RAINFORD said the observation test more or less gave a guarantee that the apparatus would be safe when surrounded by an explosive atmosphere. If the observation test shewed some weak point in the structure the final tests would not be proceeded with unless confirmation was required concerning the particular feature of design which had failed on the previous tests. During the observation test, records were taken of the pressures developed within the enclosures, and a great deal of information had been derived from those records. It was possible to visualise the type of explosion that took place inside the casing, how the flame had travelled through the enclosure, and whether any abnormal conditions had arisen through the layout of the gear. By that means quite a lot of information had been given to designers.

Capt. MACKINTOSH said Mr. Rainford had brought to their notice one of the most important subjects they, as mining electrical engineers, had to deal with. In the first place the author spoke about adequate ventilation. Capt. Mackintosh took it that if every pit had adequate ventilation there would be no need for a test officer at Buxton. He could forsee that it was practically impossible for any colliery manager to say he would never get an explosive mixture in any part of his pit, and therefore the question of flame-proof apparatus was important.

He was pleased to hear Mr. Rainford specifically refer to "flame-proof and explosion proof," and was further pleased to find that on the official certificate "explosion proof" appeared as well as "flame-proof." He had himself been up against that question on more than one occasion. People had said of apparatus: "Yes, it is flame-proof, but is it explosion proof"?

Mr. Rainford also said something about tin kettles in the mining industry, but those who knew anything about the official tests at Buxton would agree that there was not much chance of anybody installing a tin kettle enclosure in these days.

With regard to unbottomed holes for bolts he was firmly under the impression that the Mines Department would not look at a joint with unbottomed holes, and he would like to have confirmation of that.

Another important point was that it was wrong so to attempt to adapt an industrial job as to convert it into a flame-proof job for the pit. He was in entire agreement with Mr. Rainford on that point, and the sooner it was realised the better, because the lot of the colliery electrical engineer would then be much happier.

He desired to thank Mr. Horsley for his very clear explanation of the views of the Mines Department on flame-proof apparatus, and designers would be very glad to have his statement. He, Capt. Mackintosh, was keenly interested in colliery work and, quite frankly, he was glad the Mines Department were adopting such a strict attitude, because if there was one explosion in a pit due to the electrical apparatus the electrical industry would suffer very much. As long as they all tried to follow the advice given by Mr. Rainford, and carried out the views expressed by the representatives of the Mines Department on the question of design, they could feel happy in the thought they were at least doing the best possible to keep the pits safe from an electrical point of view.

The PRESIDENT said the author had stated that cast iron could be used for small enclosures and fabricated enclosures for bigger apparatus. He wondered what size of enclosure would be regarded as a small one and what would be a big one. Perhaps the author could enlighten them on that point.

With regard to studs for holding trifurcating boxes Mr. Rainford had mentioned there were two ways of putting them in, welding or rivetting, but apparently he did not approve of either. What other method was there of putting them in?

Mr. Rainford also stated that terminal boxes, trifurcating or bifurcating boxes, should be flame-proof. Was it possible to make a terminal box flame-proof? The use of the terminal box was to connect up the cables between the box and the inside of the main apparatus. The insulated studs that came through were for the purpose of connecting the cables to the internal part, the switch, and other apparatus, and if it was necessary to make a terminal box flame-proof there would have to be insulated studs on the incoming side as well.

Mr. Roseblade, continuing, said he was very interested in the remarks of Mr. Horsley concerning the effect of explosions on welded and cast iron cases. Welded cases were much lighter in construction but apparently they could be subjected to stresses which would permanently distort them. It was a question whether cast iron or welded steel was the better.

He took it that colliery apparatus was tested by a 10% methane mixture. He was not a colliery man, but he gathered it was almost impossible to get a 10% mixture in the mine, in which case would it not be better to test with pentane to make sure the apparatus would stand up to more than a 10% mixture of methane?

On one of the diagrams he noticed that the point of ignition was in a tube leading into the enclosure. He always thought the point of ignition should be in the middle of the enclosure rather than outside connected with the pipe.

Mr. RAINFORD replied that on the question of the size of the cast iron casing they could not fix a dividing line, it was necessary to treat each apparatus on its merits. Various factors had to be considered relative to size of casing, thickness of wall etc., and one could not fix a definite line as to the size to be used.

His point with reference to studs was that whether riveted or welded, they should not be considered as an easy alternative; bottomed holes should be provided with both cast iron and steel enclosures, as previously indicated.

As regards testing, the percentage range for methane was 9½% to 10½% in air, the maximum pressure mixture being round about 9.8% in air. The mixture used made the most explosive conditions as far as firedamp was concerned. A test could be made with pentane, if it was desired to know what factor of safety there was in the enclosure, but as far as mining gear was concerned the test with pentane was not of much importance. If it was tested with firedamp—actual pit gas—it was probably more satisfactory to the man in the pit when he knew the apparatus had been tested in that way. For enclosures of oil immersed gear hydrogen was used for the internal explosive mixtures and firedamp for the surrounding explosive atmospheres.

With regard to the point of ignition the spark gap fitted in the pipe line was definitely put in that position to give a rate of development of pressure similar to that which would be obtained if the motor was tested running under power. If the test was made with circulating gas, and the spark was inside the enclosure the rate of development of pressure was not so high as it would be with a spark outside in the pipe line. The circulation test was controllable by altering the position of the spark gap and the speed of the circulation.

The PRESIDENT.—Is the gas in the pipe line ignited only for testing motors?

Mr. RAINFORD.—Yes.

Mr. HORSLEY asked whether Mr. Rainford could give, from memory, any figures of the relative pressures for firedamp and pentane in the same vessel or container. His own recollection was that it ranged from 16% to about 25% higher for pentane.

Mr. RAINFORD replied that he had in mind one recent test with both gases. The pressure developed with firedamp was 50 lbs. and with pentane about 61 lbs. per sq. inch. Those figures were quite approximate. With totally enclosed vessels in experimental work the maximum pressure with firedamp was 105 lbs. per sq. inch and with pentane 120 lbs. per sq. inch, but one could not say what the ratio would be on a piece of commercial apparatus. It depennded on the amount of cooling that took place relative both to firedamp and pentane.

Mr. ANDERSON said that one of the valuable features of a meeting such as that was that people were present who were engaged in the constructional work, the manufacturing side and in the maintenance and operation of the plant. They were indebted to Mr. Rainford and Mr. Horsley for the many suggestions they had thrown out. Maintenance covered a long period in the life of a machine. Although apparatus might be turned out which was faultless, and passed all the tests imposed, if it was not properly maintained satisfactory results would not be obtained. Maintenance was a very important factor.

Mr. Horsley had been so good as to give them a guide, in so far as he said venting apparatus was viewed with suspicion—at any rate that was the interpretation he, Mr. Anderson, put upon it. With apparatus of small size, where the cubic contents of the space inside was limited, he imagined it would not be difficult to dispense with vents entirely. On the other hand with machines of a large size the difficulty might be quite a real one, because a very heavy explosion might be caused owing to the volume of gas it contained. The force of the explosion would become more severe and to him, with his rather limited knowledge, it would appear almost impossible to make a piece of apparatus like a large electric motor secure against internal explosion without the use of venting apparatus. He had the temerity to ask Mr. Horsley to emplify his remarks by indicating more precisely what he meant by "suspicious."

Mr. HORSLEY replied that the pressure did not increase seriously with the increase in volume. As Mr. Rainford told them the maximum pressure for firedamp was in the region of 105 lbs. per sq. inch. That was the theoretical pressure and it was never actually attained in practice. It tended to be more of the order of 50, 60 or 70 lbs. per sq. inch. The difficulty with large enclosures was due to the total force developed by the explosion. The rate of pressure in lbs. per sq. inch might be no higher, but when the area upon which this pressure was exerted was four or five times as great the strength of the structure had to be greatly increased.

A difficulty arose in structures of moderate volume, with aggregations of switchgear in fabricated steel tanks. The trouble there was not so much that the fabricated structure was unable to stand the firedamp explosion as that it was unable to withstand an equal but sustained pressure applied, for test purposes hydraulically. It was that difficulty to which he referred in speaking of the margin of strength in the structure. They were searching for some basis upon which they could judge the margin of strength of fabricated structures in relation to the pressure developed within them when testing with inflammable gas. They wanted to know that there was an ample margin of safety in the strength of the structure. If it was a cast iron enclosure manufacturers were usually willing to subject it to a hydraulic test up to twice the value observed on the explosion test.

He certainly did mean to say that vents and venting devices were regarded with suspicion and the grounds of the suspicion were these. Firstly, there was a temptation under stress of competition to use a vent in order to lighten, and therefore cheapen, the structure. Secondly, there was the risk that in the process of manufacture the vent might not be maintained within the narrow limits that were necessary for safety. Thirdly, there was the possibility that the vent opening might become altered in service. It might be reduced or even closed, in which case it ceased to function as a safety valve; or it might be increased so as to become unsafe. He would give a few crude examples. Assume a flange vented joint for a switchbox the flanges being kept apart by washers, 20 mils thick, round the fixing screws. When the cover was removed the washers or some of them might be lost or thrown away. In that case the safety valve had gone. On the other hand a somewhat thicker washer might be substituted, or, in the hurry of refitting, two washers might be placed where there should only be one, and that would widen the gap, making the apparatus unsafe. He also distrusted venting devices because they admitted dust and moisture freely and therefore they were unsuitable for actual coal face conditions. A venting device must be a mistake proof device: mistake proof in manufacture and mistake proof in maintenance. There was no objection to venting by rough machining; if the surface of the flange between bolt holes was machined out, great care in manufacture was necessary to ensure that the gap width did not exceed 20 mils, and such a vent was certainly wide enough to admit dirt. On the whole, venting devices were not technically necessary for the apparatus for which a flame-proof enclosure was generally necessary.

Mr. BELL remarked that Mr. Horsley's statement clearly indicated that one very important point was strength of material and strength of construction. Another point emphasised by Mr. Horsley was that as regards relief vents simplicity should be the keynote. What was known as flange protection was from the colliery point of view the simplest and most reliable. But why design apparatus to comply with a flame-proof specification when at a slightly increased cost it could be made explosion proof?

Mr. Horsley had pointed out that in certain designs permanent deformations were caused, but if fabricated structures were tested to a hydraulic pressure of 150 lbs. Mr. Bell was quite certain no explosion would cause permanent deformation of the apparatus.

With regard to the flame-proof bifurcating box one speaker had mentioned that all the connections were made external to the apparatus which was being tested and why the terminal box, or the bifurcating box should be flame-proof he could not understand.

Mr. Bell was pleased to know the Mines Department were now testing apparatus, and if the user got their certificate and maintained the plant properly it would be an assurance that the regulations were being observed.

The weight of the apparatus had no doubt increased; that was a disadvantage to those who had to pull it about, but for their own safety it was wise that the men should be educated at the start to deal with the heavier type of equipment.

Mr. RAINFORD dealing with the question of terminal boxes said one should not overlook the fact that under colliery conditions there was a liability of flash over across the terminal stems, which were in the wall of the main flame-proof enclosure. Loose connections, deteriorated insulation and coal dust were conditions which were liable to lead to flash over, and therefore it was desirable that terminal boxes should be flame-proof. Trifurcating boxes, where attached to the terminal box, came under the heading of cable entry into the terminal box and in that connection reliance had to be placed on the installation and on the maintenance men.

Capt. MACKINTOSH said he would like the point in regard to the trifurcating box to be cleared up. He had in mind an official ruling that no external conductor was to be taken into the flame-proof enclosure. If the trifurcating box had to be a flame-proof enclosure how was it possible to get the external conductor into it without breaking the law?

Mr. HORSLEY.—Let us take a simple illustration. Every time the switch is operated it is capable of causing ignition, and therfore it must be flame-proof. That is the great hazard and the terminal box is a minor hazard, but still a hazard. The greater hazard requires studs in the walls for terminal connections. The minor hazard can be covered by flame-proof joints, and by closing the cable entry; or by filling the box with compound. The designer cannot compel the electrician to install the cable so that it makes a flame-proof entry into the box, but provision can be made which, if properly used, will make the terminal box flame-proof.

Mr. BELL.—But the Mines Department only pass a flame-proof trifurcating box attached to the apparatus.

Mr. HORSLEY.—But they can give a certificate for apparatus without a flame-proof box.

Mr. BELL.—Yes.

Mr. HORSLEY.—The position is a little difficult. The Department do not seek to be autocrats: they have to proceed by persuasion: they urge that a flame-proof trifurcating box is desirable and do, in effect, require that a terminal box shall be provided which is capable of being made flame-proof with the co-operation of the user.

Mr. BELL.—Then it is taken for granted that in the terminal box there is the possibility of sparking.

Mr. HORSLEY.—There undoubtedly is.

Mr. BELL.—There is also the hazard that sparking may eventually ignite the compound filling which is probably a greater risk than the ignition of gas.

Mr. HORSLEY.—The compound filling, assuming the design and workmanship is good ought to reduce the risk of any breakdown in the terminal box.

Mr. BELL mentioned that he was only speaking from experience.

Mr. HORSLEY.—Compound properly applied will exclude moisture which is the most usual provoking cause of the breakdown of electrical insulation. Cable engineers depend absolutely on the sealing of their cable joint boxes and terminal ends with compound to preserve the insulation.

Capt. MACKINTOSH moved a vote of thanks to Mr. Rainford and to Mr. Horsley: the former, he remarked, knew what he was preaching about and practised what he preached. It had been his, Capt. Mackintosh's, privilege to visit the testing station and he had been greatly impressed with the thoroughness with which everything was carried out. If a colliery engineer got a certificate from Buxton he need not worry very much as to whether the apparatus was truly flame-proof or not.

The Branch had been honoured by the attendance of the Chief Electrical Inspector and the Chief Testing Officer. They were grateful to Mr. Horsley for the manner in which he had answered the points put to him.

Mr. BELL having seconded, the resolution was carried with acclamation.

Mr. RAINFORD and Mr. HORSLEY acknowledged the vote of thanks, Mr. Rainford observing that the interest taken in the paper was an ample reward for any trouble its preparation had involved.

MIDLAND BRANCH.

The Use of Oils in the Electrical Industries.

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

(*Paper read 9th January,* 1932)

One of the greatest problems associated with the enormous increase in the use of electricity during the last fifty years, has been the provision of suitable insulating materials. Much time and money has been spent in searching for better materials, and undoubtedly this expenditure was amply repaid when the products obtained from petroleum were investigated. At the present time petroleum provides the largest part of fluid, semi-fluid, and solid insulating media which were formerly made from vegetable oils, and resin. Petroleum technologists have willingly co-operated with manufacturers of electrical equipment and supplied them with oils suitable for the many different sets of conditions which pertain in the production, transmission, and use of electricity. Mineral oils have contributed largely to the success of the electrical industries in modern times.

The processes which must be applied to crude petroleum to obtain insulating oils of a high quality, are numerous and complicated. It is beyond the scope of this paper to give more than a very brief outline of the principal operations involved, before passing on to the methods of testing and the applications of mineral insulating oils.

REFINING.

Petroleum is abundantly distributed throughout the world and may be found at depths varying between a few hundred and several thousand feet. When the oil fields are successfully tapped by rotary or percussive drilling the crude oil is usually forced up by the high pressure which exists below. The flow of oil has then to be controlled so that the oil may be led away through pipes to a reservoir or refinery.

Crude petroleums exhibit a wide diversity of characteristics. Some are thin pale liquids, others are very viscous and almost black. In all cases except where certain crudes are suitable without treatment for use as fuel oils, the first process in refining is distillation.

Distillation.

This is essentially a physical process which utilises the difference in boiling point of the various constituents of crude petroleum, in order to effect a partial separation. Crude petroleum consists of such a large number of closely allied and completely miscible compounds that even if it were advantageous it would be quite impossible to obtain a complete separation of the constituents.

Two forms of still are used for distillation the original horizontal cylindrical vessel known as the "shell still", and the more modern "pipe still" in which the crude oil is pumped through a series of fire heated tubes and thence to a form of tower in which vaporisation is allowed to take place.

The lighter fractions readily vaporise when heated but the heavier fractions can only be distilled at a sufficiently low temperature to avoid decomposition by the use of a high degree of vacuum with or without introduction of steam.

The products of distillation chiefly depend upon the type of crude oil although within certain limits the relative proportions of the various fractions may be altered to suit the requirements of the manufacturer. Each distillate may be redistilled to obtain further separation. The result of the distillation of a number of typical crude oils is given in Table I.

Insulating oils for electrical purposes are obtained from the Lubricating Distillate and the Cylinder Stock. It should, however, be noted that a satisfactory electrical oil cannot be obtained from an unsuitable type of crude oil in spite of the most drastic refinement. Only a small number of oils will yield fractions which possess the desired characteristics so that the selection of the right type of crude is of greatest importance. The lubricating fraction usually contains wax which must be separated from the oil. The wax distillate is pumped through chilling tubes surrounded by cold brine and the wax crystals which separate out are removed by filter presses of the usual plate and frame type placed in cold rooms. The temperature of the mixture of wax crystals and oil may be as low as 15 deg. F. The wax-free oil is known as "pressed distillate" and is subjected to redistillation to give a series of oils of different viscosity.

The cylinder stock also has to be freed from wax in most cases but owing to its high viscosity the method must be suitably adapted. The oil is first diluted with twice its volume of naphtha so that the treatment may be more easily applied. The diluted cylinder stock is

TABLE I.

	Penna	Mid Cont.	West Texan.	Egyptian	Russian		Calif
Petrol & Naphtha	30	22	34	8	20	4	12
Kerosene	17	10	10	15	20	35	22
Gas Oil	24	55	14	—	30	16	25
Lubricating Distillate	5	6	18	—	24	20	18
Wax	1	2	—	—	—	0.5	—
Diesel Oil	—	—	—	44	—	—	—
Cylinder Stock	14	—	—	—	—	—	—
Coke	—	5	—	—	6	—	10
Flux	—	—	24	—	—	—	—
Pitch	—	—	—	30	—	25	—

slowly chilled to a temperature which is usually close to the cold test desired for the finished product. The separation of waxy material may be accomplished by cold-settling or centrifuging. If cold-settling is employed the liquid is left undisturbed and the low temperature maintained for several days. Two layers form, the lower one contains solid wax suspended or dissolved in very viscous or semi-sold hydrocarbons, the upper one consists of wax-free oil diluted with naphtha. The two layers are carefully drawn off and the diluent removed by distillation. The use of the centrifuge enables a much more complete and rapid separation of the chilled solution to be carried out, and the method has been widely employed in recent years.

Chemical Refining.

Physical processes such as distillation or crystalisation do not remove many undesirable constituents from petroleum. Chemical methods must be employed to obtain further purification of the products of distillation. It is interesting to note that a method first suggested as far back as 1855 is still used today almost universally in order to bring about the desired amount of refining. The process consists of treatment with sulphuric acid followed by washing with sodium hydroxide solution. Many other methods have been suggested and a few such as that of Edeleanu have attained to some degree of success, but none has proved so generally useful, technically and economically, as the original acid and alkali process.

Acid refining is conducted in large lead-lined iron vessels provided with conical bottoms which enable sludge to be easily withdrawn. The predetermined amount of sulphuric acid is slowly added whilst the oil is vigorously agitated by air blowing, pumping or stirring. The action of the acid causes the temperature to rise and steps have to be taken to prevent the temperature exceeding about 75 deg. F. The sludge which forms is allowed to settle and then drawn off at the bottom. The oil is run into another vessel where it is given an alkali washing.

Every petroleum fraction is an extremely complex blend and therefore the action of sulphuric acid is very complicated. Only a few of the more obvious reactions have been definitely recognised. Sulphur dioxide is liberated shewing the oxidising action of the acid, but the reactions which cause the deposition of the black sticky acid sludge are still rather obscure. It seems probable however, that sulphuric acid dissolves or precipitates sulphur compounds, resins, and petroleum acids, combines with nitrogenous substances, sulphonates aromatic hydrocarbons, and oxidises or polymerises unsaturated hydrocarbons. The selective action of the sulphuric acid has to be carefully controlled by adjusting the strength and amount of acid, the temperature and duration of refining, and the method of adding and mixing the acid.

The early stages in acid refinement are usually conducted with 93% to 98% sulphuric acid but more complete treatment where colourless or very pale oils are required must involve the use of fuming acid. In general the undesirable substances which are oxidisable, resinous or asphaltic, are removed by acid treatment. Subsequent alkali washing results in the removal of traces of sulphuric acid, "sulphonic acids" which are oil-soluble, and naphthenic acids which have escaped attack during the acid treatment. These substances form soaps with the alkali, and together with colloidally suspended solids frefrequently cause the formation of emulsions which are very difficult to break. Washing at a high temperature reduces the emulsifying tendency but often special steps have to be taken to bring about a proper separation of the soapy alkaline liquor from the oil.

The yield of oil from acid and alkali treatment varies according to the degree of refinement. A yield of 80% to 90% is usual for pale lubricating oils, but for A-grade transformer or pharmaceutical oils only 35% to 65% may be expected.

Refining by Adsorption.

Porous materials such as fuller's earth, animal charcoal, bone black, and silica gel, have long been known to possess the power of decolorising and purifying all kinds of liquids. These substances selectively adsorb resinous, and asphaltic compounds which are chiefly responsible for the colour of mineral oils. It is also suggested that high molecular weight naphthenic acids, nitrogenous and sulphur compounds are removed by this selective adsorption.

Simultaneous polymerisation and adsorption may occur since it has been observed that material recovered from used fuller's earth is unlike anything in the original oil.

The first material used for the absorptive refining of mineral oil was bone-black. We still see specifications for lubricating oils containing the phrase "charcoal-refined mineral oil", although the use of fuller's earth is now almost universal. Those responsible for drawing up specifications would do well to bring their terminology in line with modern practice. The term "fuller's earth" is used to describe a wide variety of highly silicious clays. The adsorptive properties are most probably due to physical structure and capillary in character.

Certain types of earth are brought to their most active condition by heating for a few minutes at 350 degs. F. to 400 degs. F. to remove the moisture and some of the combined water. Others only require to be dried at a low temperature.

Two methods are available for conducting the adsorptive refinement: Percolation and Contact Filtration.

In the percolation method the powdered and dehydrated earth is put into vertical steel cylinders in which it is supported by a perforated false bottom. Some arrangement is usually made to allow for steam heating. The oil is pumped in at the top and allowed to percolate down through the earth under a few pounds pressure. The temperature and pressure at which the oil is supplied to the top of the filter are adjusted to suit the type of oil undergoing treatment, the degree of refinement, desired, and the size of the filter bed. The earth may be used until the percolated oil fails to reach the required standard, when a regenerating process is employed to enable the earth to be used again. Most of the oil left in the filter is dissolved out with naptha and the subsequent complete removal of the naptha is accomplished by steaming for several hours. The earth then contains only such resinous or asphaltic substances as are firmly adsorbed and these are removed by burning. Fifteen recoveries by this method are normally practicable.

In the contact filtration process a small amount of fuller's earth is added to the hot oil and the mixture agitated. When maximum adsorption has taken place (usually 20 minutes) the earth is removed by filtration through the usual type of filter press. This method has certain advantages in that the plant is much more compact and allows the use of very finely divided earth, which could not be employed for percolation.

For lubricating oils the process of refinement consists of distillation, acid and alkali treatment, and filtration as described above, although certain of these processes may be omitted in special cases. Subsequently the oils have only to be blended to obtain the desired physical and chemical characteristics in preparing lubricants suitable for all types of engines, vehicles and industrial machinery.

When manufacturing mineral oils for use as insulating media the normal processes of refinement have to be modified and additional treatment given to obtain the required electrical characteristics. The chief modifications involve more intensive acid treatment with consequent lower yield, repeated earth filtration by the percolation and contact methods, and complete drying conducted with the utmost thoroughness.

Drying.

The removal of all traces of moisture is of such moment that extreme precautions are taken in this connection. Theoretically the drying of a petroleum product is a simple matter, but in practice on the large scale considerable difficulties are encountered. Only a few satisfactory and economical methods are available and they need most careful application.

Blowing the warm oil with air or inert gas serves to remove most of the moisture. Subsequent contact filtration may be advantageous. When the oil is liable to deteriorate to an appreciable extent in contact with air, an alternative method must be adopted. The hot oil is sprayed into a large vessel under very high vacuum. The elimination of moisture by vacuum is a slow process, and can only be made practicable by continuously circulating the oil and incorporating such arrangements as ensure that the oil is exposed to the vacuum in the form of fine drops or a thin sheet.

The tendency of mineral oils to deteriorate when heated in contact with air renders very difficult the process of drying to the degree required for electrical purposes.

(*To be continued*).

PERSONAL.

PRESIDENT AND CHAIRMAN OF W. T. HENLEY'S.

At the last Annual Meeting of W. T. Henley's Telegraph Works Co. Ltd., Sir George Sutton, Bart., Chairman of the Company, intimated that he proposed to retire from the Chairmanship on the 31st March, 1932. Sir George was invited by the Board to accept the courtesy title of President of the Company, to which he has agreed.

Mr. Arthur Edward Salmon has been appointed Chairman of the Company and will devote his whole time to the office.

GENERAL MANAGER OF W. T. HENLEY'S.

As Mr. Percy Rosling reaches the retiring age this year he will leave the service of W. T. Henley's Telegraph Works Co. Ltd., on the 31st March, 1932, and the Board has appointed Mr. Walter Frederick Bishop, as General Manager, as from 1st April, 1932.

Mr. Bishop was educated at the Grocer's Company School and commenced with Henley's as a junior on May 1st, 1895. He was for many years chief of the Estimating Department, and later Sales Manager, being appointed Assistant General Manager on April 1st, 1925. He has been a member of the Wiring Regulations Committee of the Institution of Electrical Engineers for many years; representing the Cable Makers' Association. He is also a member of the Statutory Committee appointed under the Electricity (Supply) Act, 1926, and he is a Past President of the Association of Mining Electrical Engineers (London Branch). For a number of years he was a member of the Electrical Development Association Council.

Mr. Bishop has always taken a keen interest in the social side of the Staff activities of Henley's Company and for some years he was Chairman of Henley's Social Club Committee.

CORRESPONDENCE.

THE EDITOR,

Banksman Control of Electric Winders.

I notice in Mr. T. H. Williams' Inaugural Address in your March isue, dealing with Electric Winder Control, Page 329, he says the idea of a Ward Leonard Winder being controlled by a banksman may appear to be more of a day-dream.

I am sure it will interest Mr. Williams and many of your readers to know that The Metropolitan-Vickers Electrical Co., Ltd., installed two completely automatic Ward Leonard Winders last year, one at Broken Hill North, and the other at Broken Hill South, N.S.W., which are arranged to work from any of fourteen levels and are controlled by a single push button operated by a banksman at whichever level is being worked.

These sets are designed to wind nett loads respectively of :—

13440 lbs. nett at 1710 feet/min., from a shaft depth of 2780 feet.

and

11200 lbs. nett at 1750 feet/min., from a shaft depth of 2090 feet.

In each case the automatic control has been applied to Skip Winding.

Both these sets are giving complete satisfaction.

Trafford Park, Manchester. A. E. du Pasquier.
29th March, 1932.

THE EDITOR.

Lighting in Mines.

At a meeting of The West of Scotland Branch held in November last a discussion took place on Lighting in Mines. In reading over a report of the discussion published in the February issue, I find I have erroneously stated (page 284) that "the incidence rate for Nystagmus is much higher for Scotland than for the whole of Great Britain or South Wales and Monmouthshire." I should have mentioned that this incidence rate was based on safety lamps only and did not apply to total persons employed. This was, perhaps, an unfair comparison as I find that for 1930 the incidence rate for total persons employed underground in Scotland was about 5 per 1000 while the figure for Great Britain was 4.39. The incidence rate was highest in North Wales and North Staffordshire where certificates were given in respect of 12.36 and 11.53 respectively per 1000 wage earners employed below ground in coal mines.

Glasgow, R. D. ROGERSON.
5th April, 1932.

METRO-VICK "GIRL" CALENDAR.

For many years past with the advent of spring the "Girl" Calendar of the Metropolitan-Vickers Electrical Company has received cordial welcome in electrical circles.

The subject selected for 1932-3 is Miss Betty Stockfield, an Australian girl, who is now starring in British Films and who has been associated with several notable screen triumphs. She and Owen Nares are engaged at the present time in making a new Naval Film at the Ealing Studios. The selection of Miss Stockfield's portrait for this utilitarian display will meet with the unanimous approval of engineer recipients of the Calendar.

NEW ELECTRIC WINDER EQUIPMENT AT THE WATNALL COLLIERY.

First Installation in Great Britain of the M.V. Hydraulic Slip Regulator.

The electrification of the winder at the Watnall Colliery of Messrs. Barber Walker & Co., Ltd., is particularly notable as the equipment provides the first example of the M.V. Hydraulic Slip Regulator to be installed in Great Britain, although eight similar equipments were successfully installed in South Africa and Australia during 1931. Furthermore, special interest attaches to this installation in that it has effectively met conditions which must exist in numerous collieries, where the replacement of a steam winder or an increase in the size of an existing electric winder has hitherto been considered an uneconomical proposition due to the restricted capacity of existing feeder cables.

The Watnall Colliery was formerly served by a steam winder which had been in use for a large number of years. For reasons of economy it was decided to replace this by an electric winder incorporating only a very few portions of the original equipment. After investigating a number of schemes with geared a.c. motors and various drum profiles Messrs. Barber, Walker & Co., Ltd., selected Ward Leonard Ilgner equipment incorporating the hydraulic slip regulator which the Metropolitan-Vickers Electrical Co., after prolonged investigation had recently brought to the stage of commercial success for winding purposes.

The Company's Moorgreen power station, about three miles away, supplies power to the colliery and adjoining brickworks by means of an overhead line at 3000 volts a.c., these having been electrified a number of years previous to Christmas 1931, when the new winder equipment was installed. The total load before the installation of the electric winder was approximately 530 k.w. at 0.83 power factor when running at full output, resulting in a voltage drop of approximately 11% due to the line. It was therefore impossible to add an a.c. winder as the voltage drop would have been excessive during the accelerating periods. Hence it was necessary to provide for equalisation of the winder load by means of a flywheel motor generator set in conjunction with Ward Leonard control.

With a motor generator set driven by an induction motor, the additional load would have increased the voltage drop to about 18%. The hydraulic slip regulator has, however, made possible the use of a synchronous induction motor for driving the motor generator set. By running this motor at a leading power factor, the power factor of the total colliery load has been raised to 0.95, with the result that the maximum voltage drop at full output, with the winder running, is now approximately only 15%. Due to this power factor improvement the k.v.a. demand on the power station is also lower than would have been the case if the motor generator set had been driven by a variable speed induction motor. Thus the addition of the winder equipment described has resulted in an increase of only about 24% in the k.v.a. demand, whereas a similar equipment driven by an induction motor of normal design would, for the same output, have resulted in an increase of 40%, even if the winding load were absolutely balanced by the Ilgner set.

The use of the hydraulic slip regulator therefore effects not only a considerable initial saving in the amount of extra generating capacity required but also a continuous saving in generating costs.

The motor generator set is driven by a 250 h.p. synchronous induction motor running at 1000 r.p.m., with its exciter mounted on the free end of the shaft. The impeller portion and casing of the hydraulic coupling is driven by this motor and the runner portion drives the flywheel and d.c. generator. The flywheel is of cast steel, machined all over, and weighs 4 tons. The generator is of the compensated type, rated at 250 k.w. at 250 volts, and is directly connected by cables to the winder motor.

The hydraulic coupling comprises an impeller portion of high tensile aluminium alloy overhung from the rotor shaft of the synchronous induction motor, facing which is a similar cast iron runner portion carried on a steel stub shaft which is overhung from the flywheel shaft. An aluminium alloy casing bolted to the rim of the impeller encloses the runner. The opposing faces of the impeller and runner are hollowed, the space between

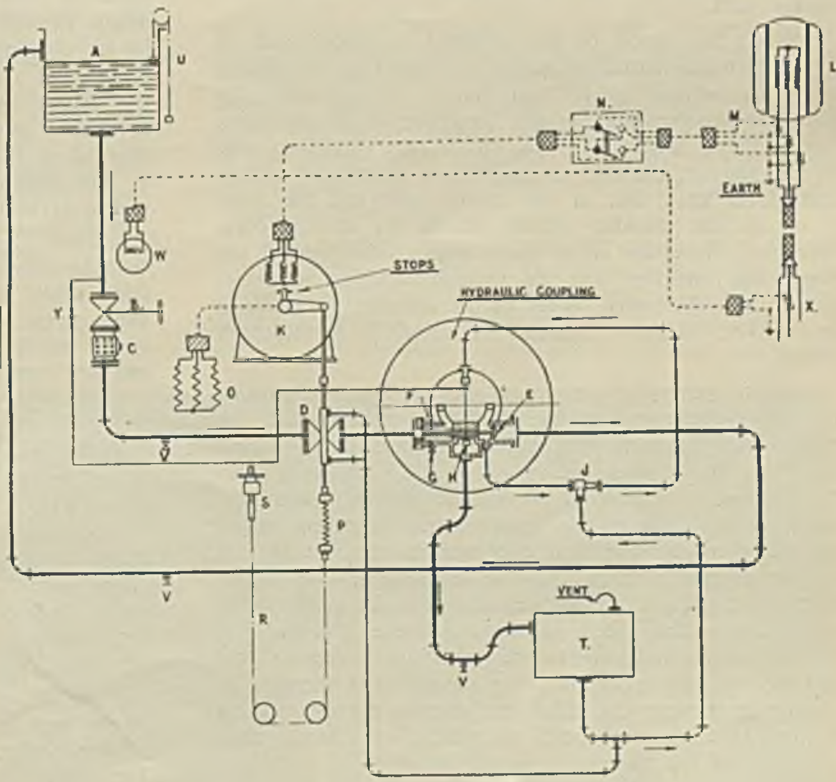


Fig. 1.—Diagram of Arrangement of the Control System.

A.—Gravity Oil Tank.
B.—Sluice Valve.
C.—Filter.
D.—Oil Governor Valve.
E.—Automatic Shut-off Valve.
F.—Spring.
G.—By-Pass Adjustment.
H.—Drain Port.
J.—Ejector.
K.—Torque Motor.
L.—Main Synchronous Induction Motor.
M.—Series Transformer.
N.—Torque Motor Switch.
O.—Torque Motor Resistance.
P.—Torque Motor Spring.
R.—Roller Chain.
S.—Adjustment for Spring.
T.—Drain Tank.
U.—Oil Level Indicator.
V.—Drain Cock.
W.—Horsepower Meter.
X.—Current Transformer.
Y.—Stop Valve.

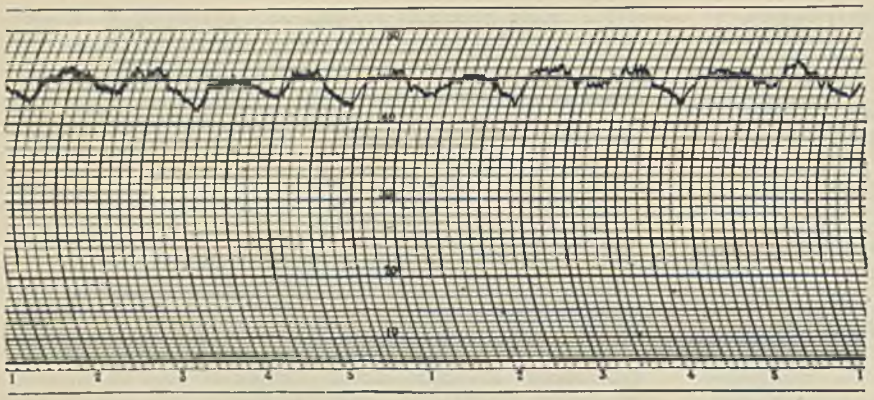


Fig. 2.—Typical Ammeter Graphs shewing Equalising Effect of Hydraulic Slip Regulator.

them forming an annular chamber of elliptical section having a round central core and divided into separate cells by radial webs. A stationary cast iron manifold arranged concentrically with the stub shaft is supported on the bedplate by means of brackets. From an overhead gravity tank oil is delivered by piping to this manifold which communicates, through ports in the runner, with the annular chamber, from which it escapes into the casing. It then passes through adjustable nozzles into an outer chamber in which, attached rigidly to the manifold, is a stationary tube in the form of a scoop, by which it is picked up as a result of its rotation and discharged under pressure through a return pipe to the gravity tank.

When the speed of the flywheel is below that of the synchronous induction motor, the speed of the runner is correspondingly lower than that of the impeller, the difference representing the slip occurring in the coupling. Under these conditions, the oil in the impeller side of the annular chamber is subject to a greater centrifugal force than that in the runner side and the body of oil in the chamber rotates about the central core. Therefore, since the oil is continuously interchanged between the impeller and the runner, energy is transferred from the radial vanes in the impeller to those in the runner, thereby causing the coupling to transmit torque.

If the generator torque is greater than that transmitted by the coupling, the slip will increase and the runner and flywheel will drop in speed, the flywheel supplying the surplus energy required by the generator. By suitable regulation of the torque transmitted by the coupling, the load on the synchronous induction motor and therefore on the source of supply may be limited to the average demand of the equipment, the torque fluctuations due to the momentary peak loads being equalised by the speed variations of the flywheel. If on the other hand, the torque transmitted exceeds that absorbed by the generator, the runner will increase in speed, decreasing the slip, the excess energy passing to the flywheel, the speed of which, of course, rises with that of the runner.

The energy transmitted by the coupling at any particular rate of slip is proportional to the mass of oil circulating in the annular chamber, and therefore, by suitably controlling the quantity of oil admitted, the torque transmitted may be continuously regulated.

The arrangement of the coupling control system is shewn in Fig. 1. The oil supply is varied by the action of a valve D which is closed by the movement of a torque motor K. This is energised from a series transformer M connected in the supply to the synchronous induction motor L and acting against the tension of a specially calibrated spring P. Immediately the current supply reaches a predetermined value, the pull exerted by the torque motor equals that exerted by the spring, and any tendency for the current to increase above this value causes the valve to start to close, so limiting the torque transmitted by the coupling and permitting the slip to increase. The valve is of a specially balanced piston type and, together with the torque motor, is almost frictionless and of very low inertia, so that the response to any change of load is extremely quick and accurate and the governing is consequently kept within close limits.

Oil thrower rings are provided in the coupling to prevent the escape of oil from the manifold, and all the surplus oil drains by gravity to a sump tank T under the floor, from which an ejector J, operated by the discharge pressure returns it to the system.

A special valve E situated in the manifold is arranged to close the discharge pipe by the action of a light spring immediately the delivery ceases, in order to prevent oil from flowing back through the scoop tube when the set is stopped.

Mounted on the wall alongside the set is a sluice valve B arranged in the delivery pipe, by means of which the oil supply may be controlled when starting up or shutting down. Adjacent to this is a pilot valve Y through which a small supply of oil is admitted to the thrust bearing between the impeller and runner to ensure adequate lubrication when the main flow is shut off at the sluice valve. A filter C is also arranged in the delivery pipe to collect any foreign particles which might be present in the oil.

When it is required to start the motor generator set, the synchronous induction motor is first started up alone with the sluice valve shut and only the pilot valve open. A liquid starter is provided to bring the motor up to speed, after which the excitation is applied and the motor runs synchronously. Oil is then slowly admitted to the coupling by means of the sluice valve B and the flywheel begins to rotate. In order that the attendant may watch the load thrown on the motor while doing this, an ammeter W calibrated in horsepower, is mounted above the sluice valve. As soon as the flywheel is at full speed, the slip at this point being about 2%, the sluice valve is fully opened, the pilot valve Y closed, and the torque motor switched on to its transformer. The set is then ready to operate the winder.

The winder comprises a plain cylindrical drum 12 feet in diameter by 4 feet wide, increasing by $\frac{3}{16}$ in. at one end to allow for an extra depth of 6 ins. at one of the shafts, each cage running in a separate shaft. The winder motor is rated at 370 h.p., and at 350 r.p.m. drives the drum through single reduction, double helical gearing at a speed of 35.6 r.p.m. Control is by means of a face-plate controller operated from the driver's lever through a quadrant and pinion and arranged for Ward-Leonard control in the usual way by varying the generator excitation.

The brakes are of the post type applied by dead weight and controlled by an air engine, arranged for control and emergency operation by the M.V. patent

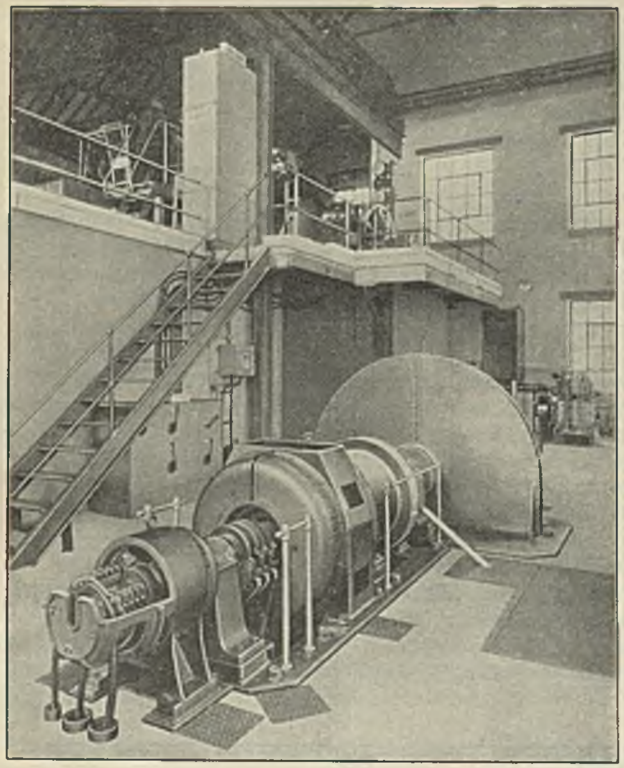


Fig. 3.—The Fly-wheel Motor Generator.

two-lever gear. A Lilly controller driven by gearing from the drum shaft provides complete overwind and overspeed protection.

The drum shaft is carried in pedestal bearings mounted on the foundations of the old steam winder and the gear and motor foundations have been constructed alongside, with the driver's platform and d.c. control equipment mounted on the original floor. Adjoining the winder house, but at a lower level, an extension has been constructed to house the motor generator set, a.c. switchgear, liquid starter, exciter set for the d.c. machines, auxiliary transformer and compressor set; communication between the two floors being by means of a stairway.

The designed output of the winder is 144 tons of coal per hour from 660 feet, the nett load per wind being two tons. Short periods of stone winding are occasionally performed with a net load of 3.2 tons, this being an overload on the equipment. Since however, there is a possibility of successive stone winds withdrawing energy from the flywheel at a higher rate than it can be restored, it is sometimes necessary, when a large amount of stone is to be raised at one time, to increase the torque transmitted by the coupling in order that the flywheel may return to speed after each wind. A handwheel (S in Fig. 1) operated a screw is therefore provided for increasing the spring tension opposing the torque motor, so that the regulation may be set for operation at a higher average load than that normally used for coal winding.

The accuracy of the load equalisation effected by the hydraulic slip regulator is clearly shewn in the diagram, Fig. 2, which shews a typical portion

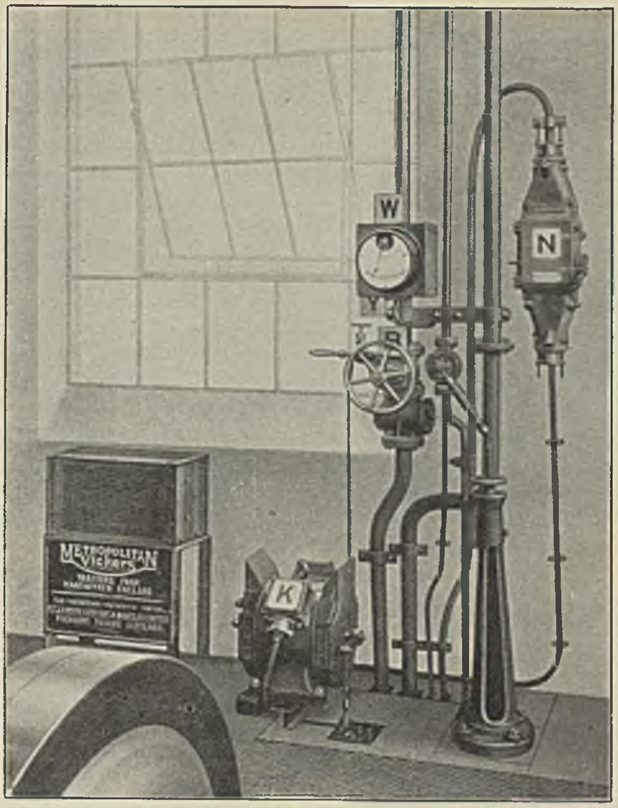


Fig. 4.—Controls for Hydraulic Slip Regulator.

of the graph of a recording ammeter connected in the synchronous induction motor supply circuit during coal winding. The vertical and horizontal scales on the graph represent amperes and minutes respectively. It will be noted that the maximum variation in load is about 5% of the average load, although the output of the winder motor during each wind varies between 500 h.p. load and 150 h.p. regeneration.

The erection of the equipment was carried out by Messrs. Barber, Walker & Co. without interrupting the normal working of the colliery. The extension of the winder house was completed and the motor generator set and all auxiliary gear erected and tested, and the winder

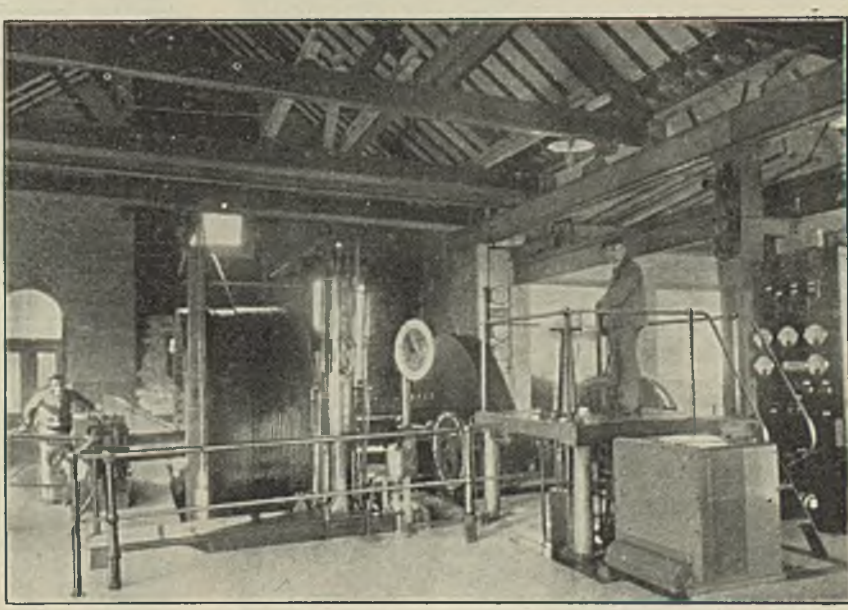


Fig. 5.—General View of the Winder.

motor foundations constructed while the steam winder was working; and everything was made ready for the change-over during the Christmas shut-down of the colliery.

As soon as the last wind had been completed by the steam winder, this was dismantled and the mechanical parts of the new equipment erected on the original foundations, using the original holding down bolts. The motor and gears were also moved into position and the necessary connections made. The new plant was ready for winding within 96 hours of the commencement of the work and coal was being raised uninterruptedly after the conclusion of the normal shut-down of one week.

The main contractors were the Metropolitan-Vickers Electrical Company, who were responsible for the whole of the equipment. The mechanical portions of the winder were manufactured by Messrs. Fullerton, Hodgart & Barclay, and the hydraulic coupling by the Hydraulic Coupling & Engineering Co. Ltd.

This installation of the hydraulic slip regulator is but a further example of the progressive policy of Messrs. Barber, Walker & Co. who during recent years, have, in conjunction with the Metropolitan-Vickers Electrical Co. Ltd., installed at their collieries the first examples in Great Britain of the following important new developments in winder control and operation.

(a) The M.V. Stubbs-Perry system of Flywheel Equalised Turbo-Electric Drive, by means of which the d.c. generators supplying a winder, together with the equalising flywheel, are directly driven through reduction gearing by means of a high speed condensing turbine. This system entirely separates the winder load from the colliery supply and ensures a uniform steam demand and extremely efficient utilisation of the steam generated. The first equipment was installed at the Harworth Colliery of Messrs. Barber Walker & Co. Ltd. in 1924 and was followed by a second equipment in 1925. Both these equipments have since been in continuous satisfactory operation and have been fully reviewed from time to time in the technical press.

(b) The M.V. patent Two-Lever System of Winder Control which eliminates the separate lever for emergency tripping and resetting of the brakes. In this system a rocking lever which interconnects the driver's brake lever and the brake engine is supported on a fulcrum which can be moved vertically. Normally this fulcrum is maintained at its highest position by a solenoid. Emergency braking is carried out by de-energising the solenoid which permits the fulcrum to fall and applies the brake fully, regardless of the position of the driver's brake lever. For resetting, the brake lever is moved to the "on" position which movement lifts the solenoid plunger and fulcrum, so relieving the solenoid of the duty of raising the weight of the fulcrum. When this system was first developed, it was incorporated in both the winder equipments at Harworth Colliery with complete success. Since then it has been included as the standard equipment for all electric winders supplied by the Metropolitan-Vickers Electrical Co. Ltd.

(c) The Lilly Overspeed and Overwind Controller which provides complete protection against overwind, overspeed and delayed retardation, and also compels the correct speed reduction on approaching bank. The accuracy and reliability of this controller mark a large improvement over the crude and cumbersome overwinders previously available. The Lilly controller is merely called upon to open an electric contact when prearranged limits are exceeded and is in consequence constructed as an instrument of precision and refinement far in excess of former standards. It was introduced into Great Britain by the Metropolitan-Vickers Electrical Co. Ltd. in 1926, and the first was installed at Harworth Colliery with complete success. Large numbers have been supplied since both at home and abroad.

(d) The M.V. Patent Brake Governor which has recently been brought to a state of perfection and incorporated in numerous large equipments in South Africa and Australia. The first governor, whilst still in the experimental stage, was fitted to the Harworth No. 2 Winder and tested under operating conditions for a considerable time, as a result of which the present design was developed and has given satisfactory service on that equipment since June 1931. The governor is designed to limit the rate of deceleration of the cages under all conditions of speed and loading. Under emergency braking conditions a safe maximum rate is imposed, thereby keeping the stresses in the ropes and other portions of the winder within safe limits. By this means complete protection is ensured against the danger, prevalent in large equipments, of the powerful brakes necessary for unbalanced conditions being too violent for normal balanced winding. Under normal braking conditions the rate of deceleration is positively determined by the position of the driver's lever, thus improving the precision of the braking control.

CALLENDER'S JUBILEE.

To go back fifty years into electrical history is practically to turn to the genesis of one of the greatest world interests of today. The unbroken chain which has with ever-increasing strength linked the name of Callender with electrical progress since April 12th, 1882, merits due acknowledgment and the present Callender's Cable and Construction Co., Ltd., will fittingly appreciate the flood of congratulations greeting their jubilee.

Though the official record of the present Company is held to be as from the foundation of Callender's Bitumen Telegraph & Waterproof Company on 12th April, 1882, the origin of the firm dates back to the "seventies." William Ormiston Callender, the father of the family, was interested in asphalt and bitumen from the advent of those materials into this country and introduced into England monolithic asphalt paving for road making. Having acquired an interest in part of the Trinidad Lake, he and his two sons, Thomas Octavius (now Sir Tom) and William Marshall, founded the business of Callender & Sons in 1877 for the furtherance of the use of Trinidad bitumen. This firm was instrumental in bringing into practical use in this country the asphalt deposits of the well-known lake. Large quantities of bitumen were refined and used for road-making and building purposes, but its uses for electrical work were constantly considered. This practical knowledge of the road-making business proved of great value to Callender's when they began to carry out complete contracts for both the making and laying of underground mains.

In those early days the only outlet for insulated wires was in connection with the electric telegraph. The energies of Callender & Sons were devoted first to this possibility, but when Swan and Edison brought into practical use the electric glow lamp it became evident that there was a field in which some material such as Callender's were making could be effectively employed for the heavy mains which would evidently become necessary.

Any product of bitumen in its natural state was useless as it was easily affected by heat. After lengthy experiments and many failures, it was discovered that a combination of certain palm oil residues with bitumen produced a material that could be vulcanised and in consequence could be employed as a covering for heavy electric cables as well as light electric telegraph wires. As a result of this experimental work Letters Patent (No. 4409) were granted to Mr. W. O. Callender on 11th October, 1881, for " Improvements in the manufacture of telegraph conductors and materials for covering and insulating wire or other conductors used for telegraphic, electric or similar purposes."

The Patent Specification set out the particulars of the manufacture of the substance that was to become so well-known in the electrical industry as " Vulcanised Bitumen ". It was to develop this discovery that the Callender Bitumen Telegraph & Waterproof Company, Limited, was formed, with a directorate consisting of Mr. D. H. Anderson (Chairman), Messrs. W. O. Callender, Henry Drake, and D. P. McEuen, with Mr. Tom Callender as Manager and Mr. James D. Sargent as Secretary. The new Company took over the bitumen refining and waterproofing business, with the patents and office of Callender & Sons at 101 Leadenhall Street, and proceeded with the manufacture of insulated wires and cables. Sir Samuel Canning (who, jointly with Lord Kelvin, was famous for his Atlantic cable experience) was appointed Consulting Engineer to the Company.

Mr. W. O. Callender, who retired from his active directorship in 1903, and died on 14th March, 1908, at the age of 81, is thus recognised as the founder of Callender's business as electric cable manufacturers.

Early in 1883 Sir J. R. Carmichael was appointed Chairman of the Board, and at his death in the following June was succeeded by Sir George Prescott, Bart. In 1894 the Directors were able to report that, in spite of several powerful competitors, " out of the 82 electric light stations now in existence or under construction in Great Britain, this Company has supplied their mains to 38 of them ". During the same year Sir George Prescott died and his place as Chairman of the Board was taken by Mr. Henry Drake, one of the original directors.

Fourteen years of active trading saw such an extension of the Company's business that an enlargement and reorganisation became necessary and on the 24th July, 1896, Callender's Cable & Construction Company, Limited, was registered with a capital of £100,000. The new foundation took over the entire interests and contracts of the former Company, and the new Board of Directors consisted of Mr. Henry Drake (Chairman), Mr. Tom Callender (Managing Director), Messrs. W. O. Callender and D. P. McEuen, Lieut.-Col. G. A. Elliot and Major W. M. Mackenize, with Mr. Theodor Petersen as Assistant Manager and Mr. S. G. Lambert as Secretary. The Directors reported in 1898 that the value of contracts in hand exceeded half-a-million sterling.

Since April, 1895, the Head Office had been at 90 Cannon Street, but continual growth soon necessitated larger premises and at Easter, 1901, the Company moved to Hamilton House, Victoria Embankment, from which headquarters the destinies of this ever-growing concern are still directed.

Sir J. Fortescue Flannery, Bart., the present chairman, was appointed Chairman of the Board of Directors in 1904, and his present fellow-directors, Sir Malcolm Fraser, Bart., G.B.E., and Sir Ernest Moir, Bart., were both elected in 1924. Mr. Theodor Petersen, who entered the service of the Company as Assistant Manager in 1895, joined the Board in July, 1930, as Assistant Managing Director. In 1932 Mr. T. O. Callender, the son of the Managing Director, was appointed a Director of the Company. Since 1917 Mr. Howard Foulds has occupied the position of Secretary to the Company and its numerous subsidiary concerns.

Sir Thomas Octavius Callender, J.P., M.I.E.E.

It may be of interest to note that in 1901 the issued share capital was £375,000 ; in 1920 this had increased to £1,300,000, and today the amount is £1,916,000, excluding debentures and large undistributed resources and reserves.

We are able to reproduce here an excellent portrait of Sir Tom Callender who has controlled with such conspicuous success the fortunes of the Callender Company for fifty years. He was born in Glasgow in 1855, the eldest son of the late William Ormiston Callender, and was educated at Greenock, in London, and later at Boulogne-sur-Mer. The outbreak of the Franco-Prussian War made it necessary for him to leave France and he later entered his father's office in London, devoting himself to the asphalt paving and bitumen refining business. It was not long before Mr. Callender was at work on the Continent, visiting many different places and at one time spending nearly a year in Roumania when the entire city of Jassy was re-paved. Another journey, this time to St. Petersburg in 1880, was instrumental in concentrating his interest on electrical work. For, during this stay in the Russian capital a visit was made to the Opera House and he was greatly impressed with the illumination provided by many Jablochkoff candles ; an electrical innovation that was to be seen at Covent Garden Opera House three years later when Callender's installed the necessary underground mains. Mr. Tom Callender travelled much throughout the Continent of Europe and later in the U.S.A. The outward passage was made in the Cunard S.S. Scythia, which was lighted by paraffin lamps, while the homeward journey was made in the Cunard S.S. Servia (then on her maiden voyage), the first large liner to be equipped with an effective electrical installation. Mr. Tom Callender was so interested in this development that he began a lifelong friendship with Mr. J. F. Albright, Messrs. R. E. Crompton and Company's representative on board, who later became widely known in the electrical world as a partner in that firm. Upon Mr. Tom Callender's return he pressed his firm to devote all possible attention to electrical matters, with the result that the new Company was formed, and this marked the beginning of Callender's active interest in the electrical industry.

Mr. Tom Callender was appointed Manager of Callender's Bitumen Telegraph and Waterproof Company at its inception in 1882, and occupied this position until the reorganisation and registration of Callender's Cable and Construction Company in 1896, when he was appointed to the Board as Managing Director, a position that he still holds. Valuable assistance was given him in those early days by his brother William and subsequently by his brother James, both of whom have unfortunately passed away. The controlling genius of the extensive Callender interests was honoured by Knighthood in June, 1918, and this well-deserved recognition gave the greatest pleasure to the numerous friends of Sir Tom and Lady Callender—feelings which, in every way, were shared by the Company's large staff in all parts of the World. Happily he is still as active as ever in the interests of Callenders and moreover is able to give many other great industrial concerns the benefits of his directive talents. Sir Tom is on the Boards of the Lancashire, the Yorkshire and the Scottish Electric Power Companies, is Chairman of the St. Helens Cable and Rubber Company and the Herne Bay and District Electric Supply Company, and is a Director of the Anchor Cable Company, the Enfield Cable Works, W. T. Glover & Company, and Thomas Bolton & Sons. Sir Tom is also a director of electric supply and manufacturing organisations whose spheres of activity are located in India, Egypt, East Africa, the Near East, South America, the Sudan and the U.S.A., and in addition is a Vice-President of the Federation of British Industries.

It is possible at this writing to mention only by name those who today are most closely concerned with the organisation and control of the vast Callender interests. Mr. Theodor Petersen has served the Company since 1895: he is now Assistant Managing Director. Mr. P. V. Hunter, well-known for his technical work in regard to super-tension transmission and "split-conductor" protection systems, is joint Manager and Chief Engineer. Mr. Charles Pipkin joined Callenders in 1888 and is now Joint Manager. Mr. Tom Callender, Sir Tom's only son, is chief of the Company's marine department. Mr. T. B. Collard joined the staff in 1895 and is the London Contracts Manager. One other name may be introduced—that of Mr. W. C. Knight who became a Callender man in 1898 and who, since 1901, has been in charge of the Company' Colliery Department centred in Sheffield.

Callender's connection with coal mining began in 1891 when they executed a contract at Abercanaid Colliery, Merthyr, and so were associated with the installing of one of the first electric underground haulage systems for replacing pit ponies ever used in this country. During the forty years which have passed the Company's participation in colliery electrification has been continuous and of increasing scope and interest.

Pole Mounting Oil Circuit Breaker for 11,000 volt Lines.

A new design of automatic circuit breaker for overhead lines has recently been put on the market by the Metropolitan-Vickers Electrical Company. This is an inexpensive hand-operated oil circuit breaker suitable for open-air pole mounting, on the side of a power transformer, or on a floor-mounting stand. A valuable and unusual feature of the apparatus is its two-part construction. The upper part, which is designed for bolting permanently to a pole structure or other support, consists of a weather-proof welded steel hood or terminal housing. In this are mounted the leading-in insulators and a set of six terminal contacts of the butt pattern, each suitably insulated. The lower part is a detachable tank in which a three-pole circuit breaker is mounted and completely immersed in oil. A second set of six butt contacts on the circuit breaker unit engages with those in the terminal housing; thus the complete circuit breaker can be withdrawn from the hood and taken away without disturbing the connections to the line or the load.

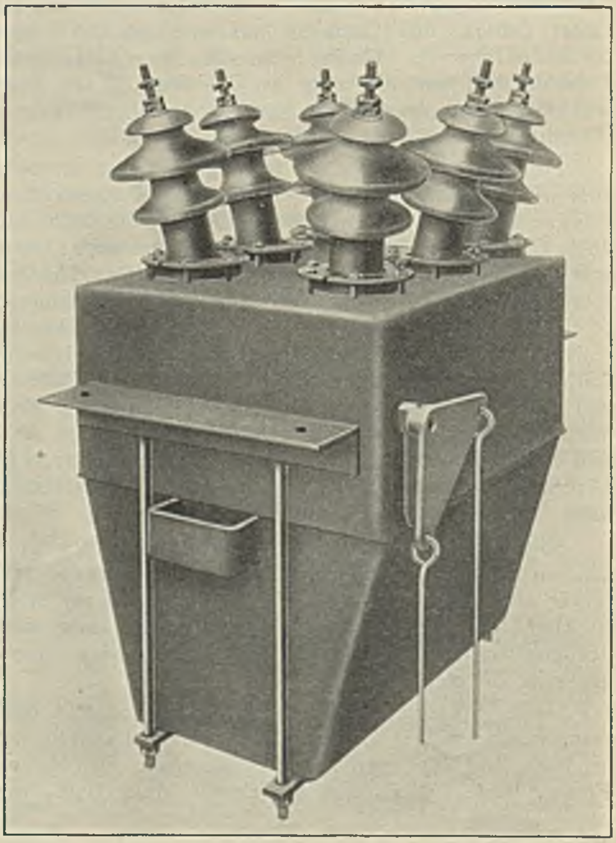
In the development of this apparatus special attention has been paid to simplicity of design and construction, with a view to reducing to a minimum the cost of maintenance, it being realised that the usual location of pole-mounted switchgear—in outlying districts—necessitates provision for easy inspection, adjustment and repair.

The circuit breaker is supplied for current ratings up to 100 amperes, for use on three-phase circuits up to 11,000 volts; it is particularly suitable for connection to secondary overhead lines, where it can be used for line sectionalising or for controlling a transformer circuit tapped off a high voltage supply.

An exhaustive series of short-circuit tests which has been carried out on this circuit breaker shews that a three-pole equipment fitted with 20 ampere (or larger) trip coils has a rupturing capacity of not less than 50,000 k.v.a. at 11,000 volts.

Various standard arrangements are available for admitting the cables. They include through insulators on top (as on the circuit breaker illustrated); through insulators on one side, suitable for transformer mounting; cable tails; cable boxes for compound filling; and combinations of any two of these.

A feature to which distribution engineers will attach considerable importance is the small bulk of the apparatus. For example, the approximate overall dimensions of a complete circuit breaker as illustrated are: height, 29 ins., width, 25 ins., depth, 16½ ins.



11000 *volt Pole-type Circuit Breaker.*