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Michael Faraday.

Though the whole world's press, and every city, society and section of the community may ring out in unison this centennial tribute to the great Faraday ; and though the particular circle of our readers, bred and brought up in the electrical atmosphere, may be as familiar with the works of Faraday as with the snapping of a tumbler switch ; we do not feel that we shall be running any undue risk of being tiresome by sharing with the reader a few further impressions of this national acknowledgment of an English genius. Faraday and his works appeal understandingly to everyone for they stand revealed and revered, unshaken in their prominence amongst all the direct creative causes of the wellbeing of man in this electrical age. We will leave to the newspapers, with their greater and more frequent editions, the task of reporting in general terms the nature and import of Faraday's discoveries ; and they too will continue to give full justice to recording the wonders and joys of numerous remarkable functions and displays organised to pay homage to the name of Faraday in this month the centenary of the greatest of all his discoveries—the existence of electro-magnetic induction—the key to all dynamo-electric knowledge and practice.

In this issue we publish general particulars of the Albert Hall Exhibition, London, and also a short Chronology of the Faraday Period. The exhibition represents the joint best effort of more than thirty scientific and industrial associations : it has given to London, the birthplace of Faraday and the lifelong centre of his works, the greatest of all the many national spectacular and ceremonial displays.

It is very likely that electrical men, being electrical men seasoned until flood lights and such have for them no wonder fascination, will respond more generally to the stimulus of reading the historical outline of the Faraday period. This country and the near Continent was beset with crises and calamities, one after another, during the whole of Faraday's life. His great work was done under vast difficulties and thus, in these serious days, one is prompted the more keenly to enquire as to what character of man could under such conditions effect so much in the gentle arts of a scientific quest. The book written by Mr. E. W. Ashcroft and published by The British Electrical and Manufacturers' Association will go very far towards satisfying that enquiry. This concentrated biography has been written specially to mark the centenary. Presumably, being a Beama production, it is intended to present a particular appeal to electrical men. The author and the publishers have done well. As we have said, most electrical engineers will feel the greater original interest in learning something of the private life of this their scientific genius.

The intellect of Faraday as revealed throughout the long chain of his scientific researches was supremely an exhibition of perfect logic : cause and effect were by him analysed to those extents which only an abnormally gifted man could devise and methodically follow. He had a profound and yet in one sense a very simple understanding of the difference between belief and knowledge. His logical mind would not permit of the investigation of spiritual matters with the means or in the the terms of material research : in his own words, he did " not think it at all necessary to tie the study of natural sciences and religion together. . . . . That which is religious and that which is philosophical have ever been two distinct things ". He was a God-fearing man of simple faith. It is said of Faraday that " all his life he kept free from the inclination to speculate about God or the meaning of existence ". Professor Tyndall said of Faraday " he hardly trusted himself to reason upon an experiment he had not seen ". Mr. Ashcroft in the biography quoted tells us that Faraday always must repeat for himself the notable experiments done by others : also that no amount of theoretical study ever had the same effect on Faraday's mind as actual experiments.

Nor can it be said that Faraday was an " educated " man, for the schooling of the blacksmith's boy, one of a large poor family, could only be scanty. He does not appear to have troubled himself to acquire a mass of detail knowledge of what other scientists had done and the principles they had promulgated in the past : he certainly did not freely accept other men's assertions and theories : he was no mathematician : his intellectual work was centred in the facts established by him for himself in the use of his five senses : though he was quick to perceive the value and the importance of his facts and could marshall them for his unerring advance to greater knowledge, he was no visionary to build on dreams.

Notions as to what the future might hold would seem to have concerned him no more than he was influenced by what the past had given. He refused, as impossible of yielding any result, to attempt to analyse spiritual beliefs : he was not interested in saving money—neither the future nor the past, to this man of facts, offered the definite materials with which Faraday sought to establish truth. Thus it can be said of Faraday that he had the temperament of an independent prospector : his was the gifted intelligence which, untrammelled and unworn by indulgence in orthodox and commonly accepted "studies", applied in fields virgin to him, uncovered priceless treasure.

Perhaps there is a salutary lesson to be learned from the Faraday Centenary which will afford inspiration when the exhibitions, flood lighting, conferences and social events are long forgotten. These days of national crises and immense difficulty are conducive to serious individual introspection. Hampered by the past and nervous of the future, we are here in the present with hard facts ready to our hands to be forced and moulded in such wise as to be of definite use.

The Trend of Progress.

The yearly blue book of the Mines Department publishing the Annual Reports of the Secretary for Mines and of H.M. Chief Inspector of Mines is of unfailing interest to those who would seek to view in true perspective the broad field of British mining. This year's edition shews that there is by no means any tendency to stand still or to accept the coal "depression" as an inevitable and abiding malaise.

In regard to technical and engineering practice the official authorities are particularly active and assertive. The qualifications of colliery technical officials are considered to be of primary importance : examinations by test papers and oral catechism are to be more searching, more complete and fairer to the candidate than in the past —fairer in the sense that the man who is the good miner shall not be penalised or rejected in favour of the smart "book-man". It is categorically stated that the time has come for the mechanical and electrical men to have clearly defined duties and that statutory personal qualifications for those duties shall then be a pressing consideration. The facilities for education are to be extended and there is to be closer co-operation between the Board for Mining Examinations and the Education Departments.

These changes appear in the Report as "recommendations" of the Committee of Inquiry into the Qualifications of Colliery Officials. Mining engineers generally are already familiar with the work and recommendations of that Committee, but it is expedient here to remind them of the great changes which are imminent and which though expressed formally as the "opinions" of a Committee will be accepted by the wise engineer as being as nearly "Regulations" as makes no matter. Mining electrical men must in any case so view the position ; for they are still strangely free from ultimate legal responsibilities.

The position of members of the Association of Mining Electrical Engineers, and particularly of those who hold the A.M.E.E. Certificates of Proficiency, will be inevitably of great import when the early pending definite statutory action is taken. So important is this matter that every sensible electrical worker in and about the mines will take immediate steps towards becoming a member of the A.M.E.E. ; he cannot possibly hurt himself in doing so, and the great probability is that he will gain very much to his advantage.

A significant feature of this latest Report is the way in which "mines lighting" crops up so prominently here and there. Definite chapters deal with the subject and there are, moreover, several other references to the importance of adequate and safe lighting in regard to specific accidents or working conditions. Haulage accidents are next in degree of frequency and gravity to falls of ground : the Report states that "in the main, what is wanted is an improvement in the conditions under which haulage operations are carried on". Better lighting is strongly advocated as an improved condition : to equip the pit pony with a light is one of those simple sensible things which one is surprised to learn has only just been started ; and, as might be expected, "the results so far are promising". Electrical men will be glad to learn that the official powers-that-be have now given an unequivocal lead to electric locomotive haulage. Here is the paragraph : "Where the conditions are suitable, haulage by storage battery locomotives on well laid heavy tracks, along roads lined with steel arches, as is done at some of the mines in Scotland, appears to be the most effective cure for haulage accidents."

There were six fatal accidents attributed to electrical gear during the year 1930. Three were in connection with trailing cables, two to faulty design and inadequate maintenance and one to the unhappy folly of opening the case of a live controller. Details of these are, as usual, to be included in the annual report of H.M. Electrical Inspector of Mines, the publication of which may be expected any day.

CORRESPONDENCE.

A Turbo-Alternator Problem.

The Editor.

Referring to the published discussion (*M.E.E.*, August, 1931, page 57) on the above subject which was submitted by Mr. William Smith at a Midland Branch meeting in May last ; no doubt you will have had by this time some communications on the subject which may provide answers to the problem, i.e.—

(1) Where does the current come from ?

(2) Why does it differ so much according to the two supplies of steam ?

I would like to submit the following which may throw some light on the dark mystery.

Some years ago, in the power house of a small mine in British Columbia a leak occurred in a steam line and a mechanic attempted to tighten the gland by a spanner on the gland bolts. He complained to me that he received a shock, but as at the time there was no electricity of above 10 volts within 50 miles I, of course, laughed at the idea and attached a wire to the steam line and boldly shewed the mechanic that I did not get a shock.

The mechanic however was so sure of the matter that he asked for someone else to attend to the fault.

I took the matter in hand and immediately felt a sharp kick as of a condenser discharge. I noticed that the spanner at the time was not touching the pipe but was in the centre of the escaping steam. This phenomenon was the cause of deep thought on-and-off for some years, until I read in one of the Journals the report of a Professor's* investigation into electrical storms when he practically established a theory which appears reasonable, i.e., that the disruption of small drops of water generated difference of potential between the parts of each drop. This process was additive so that during an electrical storm difference of potential of very great magnitude (one thousand million volts) was generated either between the clouds or between the earth and clouds. It thus appears that the generation of high potentials by this means depends upon the number of drops of water or the wetness of the steam.

This appears to offer a solution to both questions. As regards the further query of the cessation of the electrostatic charge for a period after overhaul, I think Mr. Horsley has offered a satisfactory reason for this, as the bearings were no doubt cleaned of oil and film and thus provided a path to earth nearer to the turbine or the source of generation of the electrostatic charge.

Beckenham, CHAS. H. RODDIS,
8th September, 1931. (Member, London Branch, A.M.E.E.)

* P. Lenard. Wiedemann's Annalen 1892. Vol. 46, p. 584.

The Faraday Centenary Exhibition: London.

It is appropriate that the greatest of all the spectacular events organised to commemorate the name of Faraday should be held in The Royal Albert Hall, of of which Michael Faraday was the first Vice President. It is noteworthy too that the first public exhibition of electric lighting plant and appliances in England was at the Royal Albert Hall in May 1879. The same dynamos, invented by Wilde, Gramme, Siemens and De Meritens then shown are on view in the entrance hall of to-day's exhibition.

Beams of light from 200 concealed electric projectors stationed around the gallery, each containing a 1000 watt lamp, are directed on to a huge overhead canopy of cotton cloth specially glazed. This gigantic reflector and diffuser is fireproof, ventilated, and contains 60,000 square feet of material made up of sixty sectors dyed primrose and cream and arranged alternately. It is said that the sewing occupied a hundred women four weeks and that to hoist the canopy into position was a most difficult task occupying 40 men for a week and requiring over twenty miles of rope manned by sailors and tent makers. The suspension from the roof consists of some 6000 feet of wire cable in 300 separate lengths. The reflected light radiating from this immense dome is in the nature of half-a-million candle power. The illumination is shadowless. Thirty-two half lanterns light the pilasters supporting the dome and a giant tubular lantern forty feet in length, containing sixty 500 watt lamps, illuminates the memorial dais. The statue of Michael Faraday, which is a cast from the marble statue by Foley in the Royal Institution, stands in the centre of this and is further illuminated by projectors concealed around the base.

Radiating from the Faraday statue the eight sections of the exhibition trace the development of Faraday's discoveries. At the outer circumference of the arena are exhibited the utilities which are the latest products of present day electrical civilisation. Here are shewn a modelled map of the "grid" system of the Central Electricity Board, the generating plant, transformers, switches, cables, transmission towers—even the electric irons, cookers, and vacuum cleaners of the twentieth century home. There is a working model of a super electric power station, a demonstration of the powers of liquid air, the making of electric lamps, the distillation of benzene, and apparatus in connection with ocean radio telephony.

The electric lamp making plant which, owing to conditions in the Albert Hall is a small one only, is manipulated by five operators. More than twenty different operations in the making of electric lamps are however being shown to the public. The production here is at the rate of five lamps completed every minute.

The largest exhibit is a complete regional broadcasting apparatus built for installation in the Scottish station. The cubicles are ten feet high and weigh over two tons. The transmitter consists essentially of five separate units, each fulfilling a definite function in the process of converting the low-power speech input into high-power modulated high frequency. The smallest exhibits are the tiny springs of moving coil electrical measuring instruments. These are of tempered steel finer than horse hair; 1400 weigh less than a pound.

The stands, which have been so disposed that the maximum space is available for exhibits, have a display length of nearly half a mile. Many interesting exhibits have had to be refused for lack of space, though the area of the Albert Hall is 20,000 square feet.

The following bodies and individuals have cooperated to organise the Albert Hall Exhibition and the many other attractive features which enter into the London Celebrations. The Royal Institution, The Institution of Electrical Engineers, The Faraday Society, The Federal Council for Chemistry, The British Association for the Advancement of Science, The British Electrical Development Association, The British Electrical and Allied Manufacturers' Association, The Cable Makers' Association, The Electrical Contractors' Association, The British Broadcasting Corporation, The Electric Lamp Manufacturers' Association, The British Institute of Radiology, and twenty other learned societies and industrial associations.

HISTORICAL DATES IN THE FARADAY PERIOD.

1789.—The French Revolution.

1790.—Death of Franklin.

1791.—Birth of Faraday.

1801.—Volta invents the Electric Battery. Nicholson and Carlyle decompose water.

1804.—Watts steam engine applied to locomotion.

1805.—Austerlitz—Trafalgar.

1806.—Davy in his Bakerian lecture declares that there is a single cause behind electrical and chemical decomposition phenomena.

1813.—Faraday enters Royal Institution and starts on travel in Europe with Davy.

1815.—Waterloo. Davy and Faraday return.

1819.—Oersted discovers deflection of magnetic needle by electric current.

1821.—Faraday marries Sarah Bernard.

1823.—Faraday becomes a Fellow of the Royal Society.

1824.—Carnot demonstrates the relation between heat and work.

1825.—Faraday becomes director of the Laboratory of the Royal Institution.
Stockton & Darlington Railway opened.

1831.—Faraday discovers electromagnetic induction.
First meeting of British Association.

1832.—First Reform Bill.

1832-1840.—Period of Faraday's work on chemical phenomena of the electric pile, induction, conduction and insulation.

1832.—Oxford confers D.C.L. on Faraday, Brown, Dalton and Brewster.

1835.—Faraday receives a pension from the Crown.

1836.—Ampere dies.

1839.—Penny postage introduced.

1843-1860.—Faraday's work on Light, Magnetism and Diamagnetism.

1846.—Hugo von Mohl discovers protoplasm.

1854.—Crimean War.

1857.—The Indian Mutiny.

1859.—Darwin's "Origin of Species."

1860.—Pacinottis dynamo.

1865.—Faraday resigns from the Royal Institution.

1867.—Faraday's death.

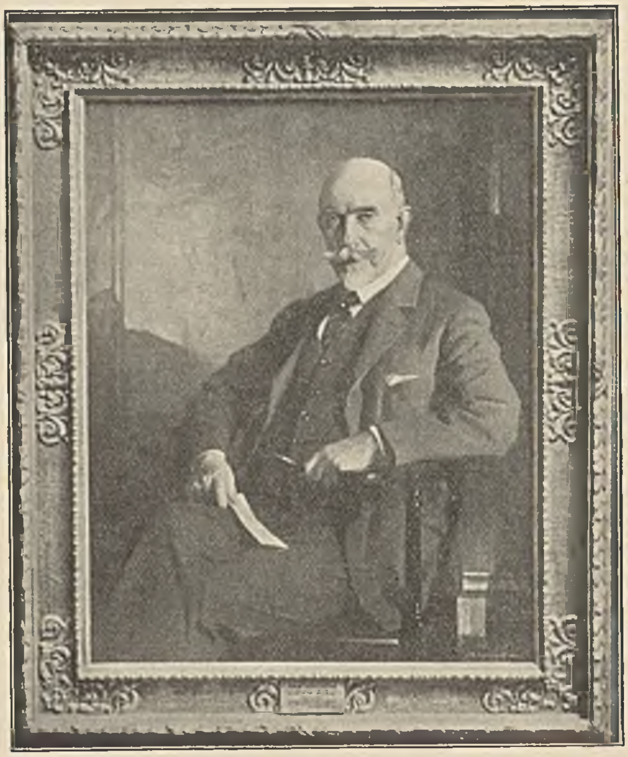
The M. & C. Jubilee.

On Sept. 4th some 1400 employees and their intimate friends foregathered—as they would say locally—in the largest hall in Glasgow to celebrate the Jubilee of Mavor and Coulson Ltd. As will be seen from the small reproduction given here, the portrait of himself presented to Mr. Sam Mavor by the employees is a very fine work of art painted by Mr. J. B. Anderson. After he had feelingly expressed thanks for the handsome gift, which he would always consider his most treasured possession, Mr. Mavor said he was glad to announce that Mavor & Coulson now had more work in hand than ever previously in the history of the firm ; the present contracts included the largest order ever placed for underground conveyors for coal production : and full employment was ensured for the forthcoming winter.

On being presented with a dinner service of Royal Doulton Ware, Mr. Coulson recalled the days of over forty years ago when the firm employed a dozen men; to-day the employees exceed 750. The firm was founded in 1881 by the late Mr. Henry A. Mavor. In 1882 it became Muir and Mavor, and in 1885 inaugurated in Glasgow the first Electricity Supply Station in Scotland. As Muir, Mavor & Coulson, it established in 1889 an electric generating plant of between 400 h.p. and 500 h.p. the first in Scotland for the supply of high tension alternating current. That business of electric supply was purchased in the early nineties by the City, and was the nucleus from which evolved the present-day Electricity Department of the Glasgow Corporation.

The firm began in 1888 the manufacture of switchgear. That was the start of the Switchgear Department, which has so grown that this year it has attained to such magnitude as to require a separate and individual organisation ; M. & C. Switchgear Limited is the new subsidiary Company with new works at Kirkintilloch.

Notable original work was the first ironclad completely enclosed electric motor (1894) which was initially designed for service in mines ; an important development of this machine was the tube-cooled electric motor for which the firm obtained a master patent in 1909.



Mr. Sam Mavor.

It was in 1897 that the firm began to build electric coalcutting machines. The early pioneering years were strenuous and discouraging ; at one time so much money had been spent—and seemed to be lost—on the enterprise that the dropping of the whole thing was seriously considered. However, the firm persevered and won through : it was the first to manufacture a completely enclosed electric coalcutter ; the first to incorporate an ironclad motor in such machines ; the first, about thirty years ago, to put on the market three-phase coalcutters with squirrel-cage rotors ; and the first to incorporate high-speed gear for flitting coalcutters on their own bases. Progress in reducing the height of three-phase coalcutters was attained by successive steps, and the Company was the first to produce a machine twelve inches high ; which may be regarded as the ultimate requisite minimum, because a miner could not work in a seam so thin as to require a machine of less than that height.

Last year the firm was awarded the largest order ever placed for coalcutters, and this year—as already mentioned—the largest order ever placed for underground conveyors for the production of coal. In 1908, the firm manufactured the first travelling carriage conveyor, the "Gibb" ; from this was evolved the gate-end loader, which the firm was the first to manufacture and market, also about 1908. About 1913, the firm imported to this country the first shaker conveyor, a type they now manufacture on a large scale. In 1926, the troughed belt conveyor was first applied underground by M. & C. The production of coalcutting machines and of machinery for handling material in bulk either underground or on the surface has now displaced entirely the firm's former general business in electrical engineering. The only electric motors now made are those incorporated in the designs of the firm's coalcutters, conveyors, loaders, etc.

Proceedings of the Association of Mining Electrical Engineers.

YORKSHIRE BRANCH.

Mining Switchgear.

E. E. GROVER.
(MEMBER)

(*Paper read in Barnsley, 21st March,* 1931.)

It is not possible to deal with all the varieties of mining switchgear within an hour's talk, and these notes will therefore cover only a few points on which special interest is centred at present or which have come into prominence through questions which the author has been asked during recent visits to various collieries. During the last twelve years a higher standard of switchgear has been required by the coal industry, both above and below ground.

The increase in the size of some of the colliery power stations has necessitated in some cases switchgear of higher breaking capacities and has justified more expenditure on protective devices. The large increase in machine mining underground has been responsible for new developments on the smaller switchgear.

More consideration has been shewn to precautions in order to provide safety from accidents and interruption to output. The publication of the new additions of the Mines and Quarries Form No. 11 in 1924 and in 1930 directed fresh attention to earth leakage safety devices, remote control of coalcutters and the earthing of cables and feeders when being examined and tested. Research work has also been carried on under the Safety in Mines Research Board, on flame-proof enclosures and on explosions within enclosed vessels and the results of these are officially recorded.

In addition to all these factors which have created interest in mining gear, a request of the Mining Association of Great Britain in 1924 to the British Engineering Standards Association has resulted in the publication of several new standard specifications including several for electrical plant such as plugs, switchgear, transformers and motors suitable for use in the mining industry.

There are several noticeable improvements which have resulted. Flame-proof switchgear can now be tested and a certificate obtained so that the much-needed standard of flame-proofing has been set up. An increase in the use of earth leakage protection has followed the recommendations in the Memoranda of the Electricity Rules. The dealing with the load current of the coalcutter motor at the gate-end switch instead of at a starting switch on the machine itself is now possible but it is still necessary to await some improvement by which a four-core cable may be used for this remote control.

The distribution of power over the coal face to a number of small units by some other means than fuse boxes has led to the improvement of the small oil-break and the small air-break circuit breakers. The use of these for distribution in the roughest of conditions has revealed weaknesses that were not apparent before. Some users are asking that this type of apparatus should not only have boiler plate tanks but should be made entirely of welded steel plates instead of using cast iron for top plates and boxes. A typical alteration is shewn in the photograph, Fig. 1. It will be noticed that on the small circuit breaker shewn the original switch has a cast iron top plate. For use on conveyors this construction was not convenient. The cast iron top plate has been replaced on the conveyor switch by a boiler top plate and instead of the sealing boxes being on top a side entry is provided to avoid unnecessary bends in the cable. The sealing glands shewn are designed to take pliable armoured cab tyre cable so that plugs can be dispensed with.

Terminal Boxes and Sealing Boxes.

For flame-proof switchgear it is a requirement of the B.E.S.A. Specifications No. 126 and 127, that the terminals be outside the flame-proof case and that the terminals be enclosed in a dustproof and moisture proof enclosure. It is not specified that the terminal box must be flame-proof and this may not be necessary if dirt and moisture can be excluded. As an extra precaution a flame-proof terminal box is probably desirable and the extra expense in addition to making it dustproof and moisture proof is small. A sealing box can be added to the terminal box or a dividing box which serves as a combined terminal and sealing box can be employed.

From the point of view of ease in disconnecting and reconnecting cables it is sometimes inconvenient to immerse the terminals in compound as this means running the compound out when gear has to be moved; and so the entirely compound filled dividing box, which comprises the terminal box and sealing box in one compartment, is at a disadvantage as regards dismantling.

If a compound filled sealing box be attached to the terminal box with the latter air insulated, it is possible to disconnect the cable ends from the terminals and remove the cable with the sealing box intact ; this has, however, the disadvantage that a removable lid has to be fitted over an opening in the side of the terminal box, with the risk of this being removed without the necessary safety precautions being taken.

Whichever of these two arrangements is used the cable ends have to be sealed below the compound so

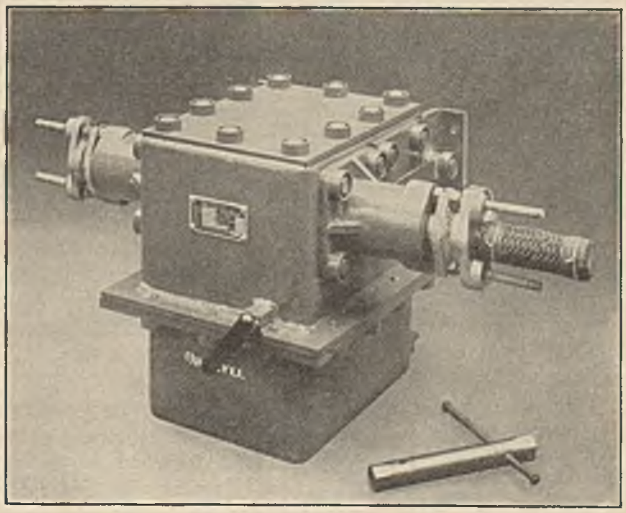


Fig. 1.—A Conveyor Circuit Breaker.

that moisture cannot percolate down the strands of the cable and impair the cable insulation or, alternatively, the cable ends have to be taped from below the compound level up to the terminals.

For small cables (19 strands or less) the cable cores may be sweated solid, but for cables of more than 19 strands, cable manufacturers consider that it is difficult to fill all the spaces between the strands. Instead of sweating the cores solid it is better to use a jumper connection consisting of a solid copper connector, which may be connected to the end of the cable core below the compound level and then connected outside the compound to a terminal.

The attachment of the cable gland to the sealing box is usually made either by: (1) bolting the gland to a face at the bottom of the box; or, (2) having a circular neck made on the gland which is held by the two halves of the box. If the terminals are made in the dividing box the second method is preferable as it enables a two-piece box to be used, that is to say, a box made in two halves with a circular opening at the lower end to take the gland. To disconnect the cable from this type of box the compound is run out and the front half of this box removed. The cable is disconnected and the gland withdrawn.

With the first type, i.e. the gland bolted to the box, the compound must be run out, the front half or a lid removed to give access to the terminals, and the bolts removed which fasten the gland to the box. This construction is not so simple for jointing or in manufacture as is the second method mentioned.

For small switchgear used at the coal face where the distribution point advances or retreats several times in a year, there are on the market detachable dividing boxes which can be plugged in and out of the apparatus without making or breaking the terminal connections. These save the labour of unsealing and resealing the compound filled boxes and save time when moving the apparatus. The sealing box is fastened to the switch case by bolts and nuts which necessitate the use of a spanner by an authorised person.

This method of obtaining portability of the switchgear means that a standard plug-in dividing box should be adhered to throughout so that any boxes of similar capacity can be plugged on to each other or to any required switch.

The ordinary dividing box in use to-day is only suitable for connecting on to its own particular make of switch and it is obvious that if it had been possible in the past to standardise dividing boxes so that all boxes of similar rating could be fixed to any make of switch, much inconvenience would have been saved. Among all the various makes of switchgear it is now hardly practical to alter the designs so that all makes of switches could accommodate one standard dividing box. The alterations would be considerable and increase the cost to the purchaser.

The same difficulty is present in altering existing switch designs to take a detachable plug-in dividing box or "flit plug." This means alterations to existing standard faces the enlarging of current transformer cases, the widening of busbar chambers and generally increasing the bulk of gear already designed for a fixed type of box.

It is probable that the difficulty will be overcome and there is room for suggestions and development of the "flit plug" feature. One idea put forward is to connect the armoured cable to the switch by means of a sealing box with terminals run in solid with compound. The two halves of the connector are bolted together and are only to be separated by an authorised electrician. Such a system might be applied to each piece of apparatus where the position of the apparatus was only temporary, including starters and rotor connections.

An effort has been made to standardise the mining plug and it is now possible to buy a 100 amp. British Standard plug wihch will fit any make of standard socket.

It is suggested that for portable mining apparatus a standard detachable dividing box to fit any make of switch is not too much to expect. If other sources of power such as water, steam, coal gas or compressed air, can be conducted to the point where the supply is required and their respective conductors connected to the engine by means of a standardised coupling, it is certain that the same condition will eventually be obtained for the conductor of electric power to the motor or other service point.

Protection against Faults.

On the switchgear for use at the surface of a mine it is usual practice to fit circulating current protection to alternators and transformers except in the case of small units of which the value may not justify the expenditure on more than overload, or overload with the addition of an earth leakage trip. The expense of the protection against internal faults of the machinery is in the nature of an insurance and it may save much damage to plant and loss of output.

On underground switchgear provided with overload, and overload plus earth leakage it is usually considered that two overloads and earth leakage constitute sufficient protection to meet the Rule 128(c) which reads:—"Such efficient means shall be provided in respect of each separate circuit for cutting off all pressure automatically from the circuit or part or parts of the circuit affected in the event of a fault as may be necessary to prevent danger."

It is however, an extra precaution to have three overload trip coils in addition to the earth leakage trip as this provides overload protection against a fault on any phase in the event of the pressure being cut off the earth leakage relay circuit. This is unusual but is a possible contingency due to an open circuit in the auxiliary circuit supplying the relay, and some engineers prefer to provide against it.

This auxiliary circuit should be connected to the outgoing side of the circuit breaker as this will ensure that with a fault to earth on the trip coil or any part of the relay circuit, the opening of the circuit breaker removes the faulty circuit from the busbars.

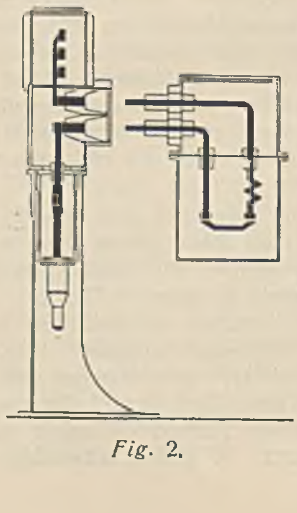


Fig. 2.

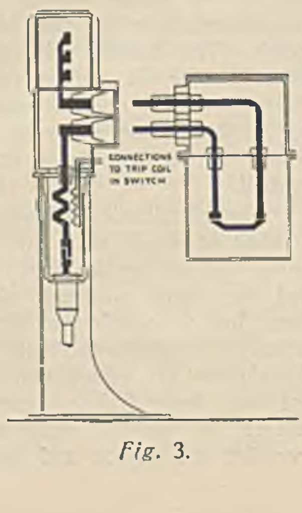


Fig. 3.

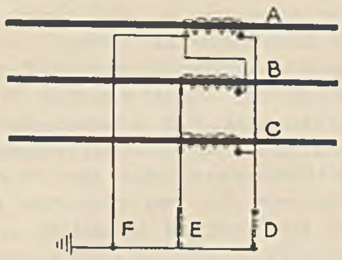


Fig. 4.—" Z " Connected Trip Coils.

As an alternative to the use of the trip coil energised by the closing of the relay, an under-voltage release coil may be used which is de-energised by the opening of a normally closed relay. In this case the auxiliary circuit may be connected on the busbar side of the circuit breaker and fuses employed to protect the busbars from a possible fault on the auxiliary circuit.

When an under voltage release coil is used the auxiliary circuit including the under voltage release coil gives warning by the tripping of the circuit breaker of an open circuit or in case of a blown fuse.

Where the trip coil is used it is advisable to place it on the feeder side of the switch rather than rely on fuses, as in that case no warning would be given of open circuit or blown fuse and the supply might not be available to operate the trip coil. By dispensing with the fuse and putting the auxiliary circuit on the feeder side the protection required for the busbars is secured without the risk of an open circuit which might be undetected.

Overload Protection.

The methods of providing overload protection are:—

(1) Direct acting series trip coils.

(2) Current transformers with directly connected a.c. trip coils.

(3) Current transformers combined with relays which open or close an auxiliary circuit, the current in which operates a trip coil.

On small sizes of mining switchgear the series trip coils are connected in the position shewn on Fig (2) where they are accessible for any desired adjustment to the overload setting. The series overload trip can be set to operate at any current from normal up to three times normal. Where current transformers are employed instead of series trip coils these are also connected in a corresponding position relative to the circuit breaker, i.e. on the busbar side, as this enables the panel to be more compact and more portable for underground use.

On switchgear for use in positions such as a power station or surface substation, where larger gear is permissible, the current transformers can be connected on the outgoing side of the circuit breaker, as shewn in Fig. 3.

The housing of the current transformers in a separate chamber is more expensive than placing them on the circuit breaker but this arrangement prevents a fault on a current transformer becoming a busbar fault and also enables the transformers to be changed easily to another ratio if the load is altered from the original specification of the order.

The usual arrangement of current transformers and relays is three current transformers with a triple pole relay. If desired each pole of the relay can be shunted through a fuse wire in order to obtain a time element. The secondary current flows through the fuse and not through the trip coil until the fuse blows, after which the current flows through the coil and trips the circuit breaker. With this connection of one trip and one current transformer per phase the power factor of the main circuit does not affect the operation on the current setting at which the circuit breaker will operate.

Another fairly common connection is to use only two trip coils in conjunction with three current transformers with the " Z " connection as shewn in Fig. 4. The operation of the tripping circuit may be affected in this case by the low power factor in one phase under certain conditions. The effects of this are shewn by the three diagrams, Fig. 5, illustrating three different conditions, respectively:

(Case 1). 100% overload on all phases (at any power factor with the same P.F. in each phase).

(Case 2). 200% overload on one phase only.

(Case 3). 30% overload on one phase only.

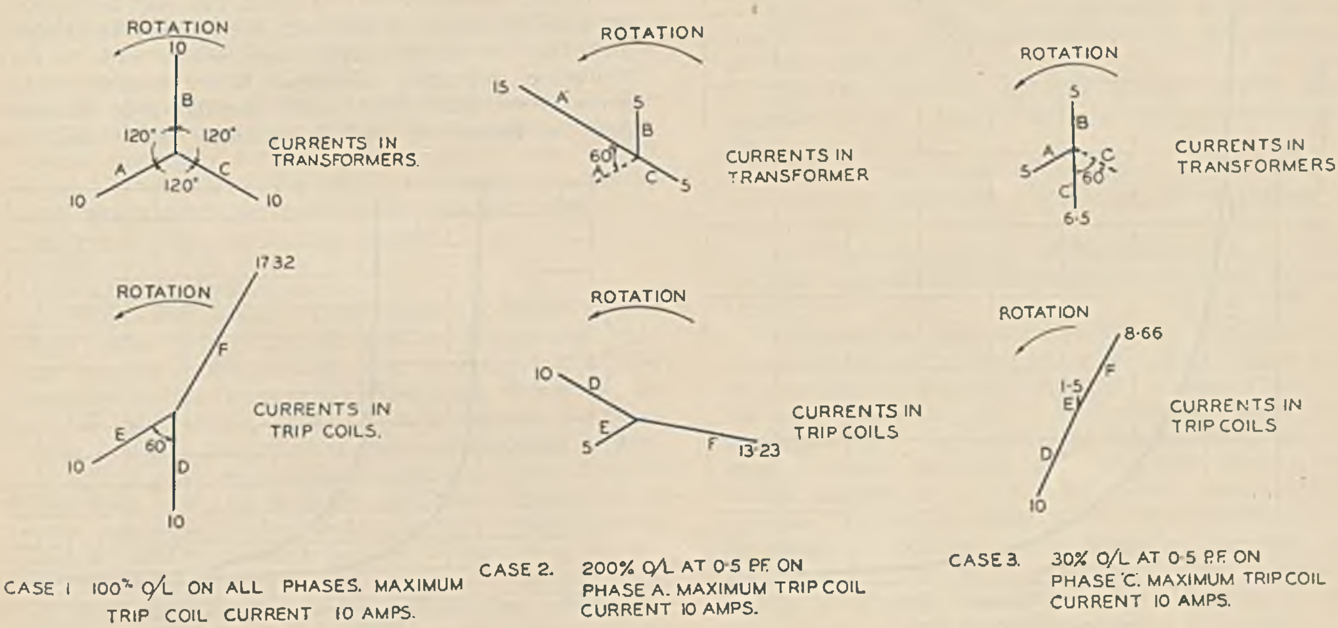


Fig. 5.

(Case 1). Assuming that the relay is set to trip at 100% overload then, with 10 amps. in the secondary circuits of the current transformers B and C the current in the relay coil E will be 10 amps., and will be 60 deg. different in phase D. Similarly, the current in D will be 10 amperes. While the 100% overload on all phases produces 10 amps. in the trip coils, D and E, the current in the return lead F will be 1.73 times the current in the coils D or E.

(Case 2). If an earth fault occurs on one phase, say phase A, giving an equivalent of say 200% overload on this one phase, this will cause a drop in the power factor on this phase. If the power factor is reduced to, say, 0.5 then it is necessary for a current of 300% of the normal to pass in phase A to operate the relay and trip the circuit breaker, assuming only full load current in phases B and C. The vector A is lagging 60 deg. (P.F. = 0.5) from its original position and it requires 15 amps. in the secondary to pass the requisite 10 amps. through the relay coil D to cause tripping.

(Case 3). If phase C were the overloaded phase and the current in C lagged 60 deg. (P.F. = 0.5) as regards the other phases, then a small overload in phase C would cause a current equivalent to twice full load current to flow in the relay coil D. The diagram shews phase C of the current transformer circuit with 6.5 amps. i.e. 30% overload and lagging 60 deg. (P.F. = 0.5) from its original position relative to the other phases. With only 30% excess current in the current transformer C the current in the trip coil D rises to 10 amps. and results in the relay tripping the circuit breaker at a current lower than the actual setting.

These three examples shew the effect of the bad power factor in one phase resulting from an earth fault on that phase and it is obviously preferable to use, if possible, a three-phase relay in conjunction with three current transformers rather than to try and economise by using only the two trip coils which do not really provide the maximum amount of safety.

Overload Protection. Time Lags.

In order to provide that the overload trip coil does not cause the circuit breaker to trip inadvertantly during a momentary surge it is usual to fit a time lag on the overload tripping arrangement. In conjunction with relays the time delay can be easily obtained by fitting a time limit fuse in parallel with each coil.

An alternative is to fit what is known as "a definite time limit" that is, a piece of apparatus with a scale graduated in seconds. The setting in seconds then provides that whatever current flows the relay will not function until the definite time of the setting has elapsed. The characteristic of the time limit fuse is obviously different to the definite time limit, and is suitable for use in power stations or substations while the definite time limit is useful for grading the settings of a number of switches in series on a surface feeder, and can be applied to either overload protection or earth leakage relays for the purpose of causing one substation in a distribution line to trip before another or several switches to trip in a predetermined sequence.

An inverse time lag can be provided by the use of a dash pot consisting of a plunger working in a cylinder containing either air or oil. Another form consists of vanes rotating in air which are driven round by a pinion by the movement of the tripping gear and so retarding the movement. These methods are inexpensive and effective as long as the inverse time element is suitable for the protection required.

The greater the value of the current the shorter is the length of time taken to operate the circuit breaker and, conversely, with a relatively smaller overload current the longer is the time before the circuit breaker trips. The characteristic of an oil dash pot time lag is shewn in Fig. 6.

It will be noticed that although this may be suitable for many situations it does not give entirely satisfactory protection for small squirrel cage motors and, in particular, to coalcutting machines. Where a squirrel cage motor is switched straight on to the line it is necessary that the momentary rush of current should not trip

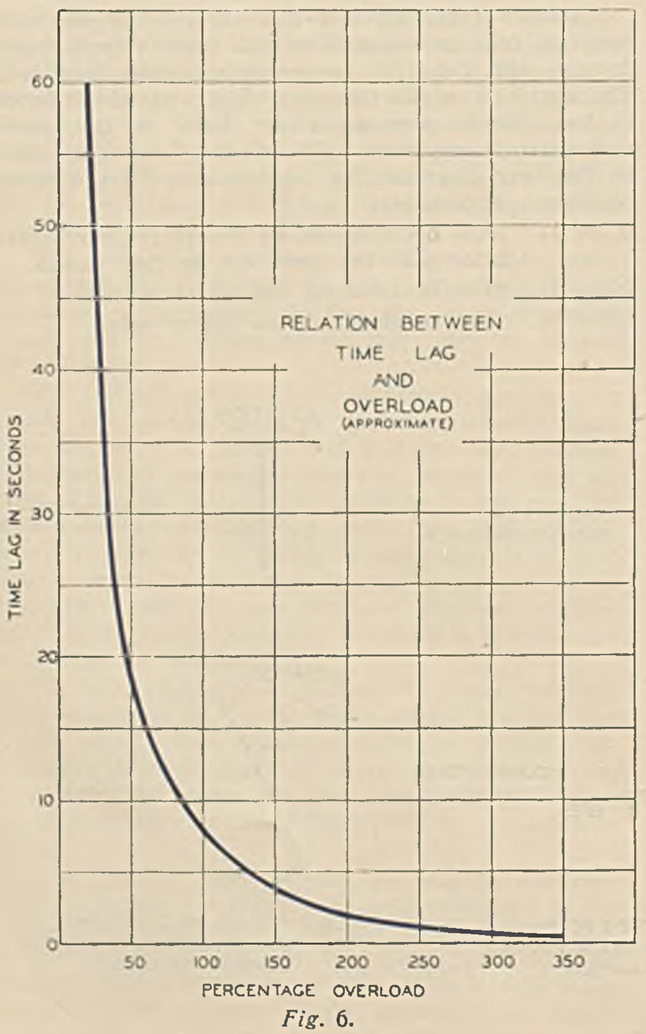


Fig. 6.

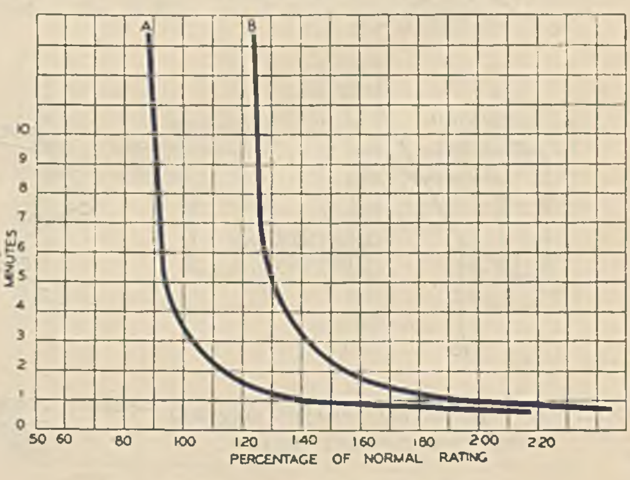


Fig. 7.—Thermal Tripping Elements.

the circuit breaker. It is necessary also to provide overload protection to prevent: (a) the motor being burnt out; (b) the cable being damaged through a long sustained overload of a small current value.

The ordinary inverse time lag does not meet the above conditions and the fuse which approximates to the requirements of (a) and (b) will not withstand the requisite starting current. Fuses are becoming increasingly unpopular for underground work, and for flame-proof gear should be avoided altogether except for very small sizes where the rupturing capacity expected out of them is negligible.

On some sqirrel cage circuit breakers a series overload coil acting without any time lag is used in conjunction with a trermal trip. The latter consists of a bimetal strip which will open or close a tripping circuit if an excess current flows and causes movement through the unequal expansion under heat of the two metals. This combination of an instantaneous overload with high setting and a thermal strip to take off the small overload sustained for a long time gives a characteristic like a fuse and is an improvement on the ordinary dash pot. Another method is to have a dash pot with a double adjustment, one for current value and another for the time. By a suitable combination of the two settings an improvement on the ordinary dash pot characteristic might be obtained. This is shewn in Fig. 7.

Earth Leakage Protection.

The addition of earth leakage protection can be made by means of a trip coil operated from three current transformers either direct or through a relay. The use of the relay causes the circuit breaker to trip at a lower leakage current to earth than the directly connected trip coil. Settings of approximately from 5% to 100% can be obtained and these cover all requirements. For underground switchgear near the coal face the lowest setting possible is usually wanted, but it is not possible to obtain very small current settings and still retain stability and a mechanically robust type of relay. Earth leakage protection has its limitation and it is well to avoid a number of switches on one circuit in series or to attempt to use the ordinary core balance type with relay for parallel feeder protection.

Parallel feeder protection requires the faulty feeder to be tripped without interruption to the healthy feeder. It is obvious that it is too much to expect this of two feeders working in parallel with earth leakage protection and overload trips on the circuit breakers. For duplicate shaft cables the settings on the surface switches should preferably be as high as 50% or 100%, which is no disadvantage and there are many installations with two shaft cables protected in this way which give no trouble from inadvertant tripping.

Testing Earth Leakage Relays.

The earth leakage relays should be fitted with a push button which can be used to operate the relay by hand in order to prove that the relay circuit and trip coil are all functioning. This relay should not be of the self resetting type. A recent request has been made to have the resetting mechanism locked so that the switch may not be closed after it has been tripped by a fault while the fault has not been removed. It is quite simple to do this, and it is recommended that a bolt be used requiring a spanner to gain access to the resetting push button.

The hand tripping of the earth leakage proves the complete circuit with the exception of the primary turns and secondary of the current transformer and suggestions have been made that a testing set might be employed so that on a typical earth fault through a resistance might be applied to a phase. This apparatus can be obtained but the use of it is deprecated underground and if it is considered necessary to test circuit breakers in this way they should be brought to bank. A single-phase transformer and an adjustable resistance to enable a current to pass through in one phase only at a time will meet this requirement.

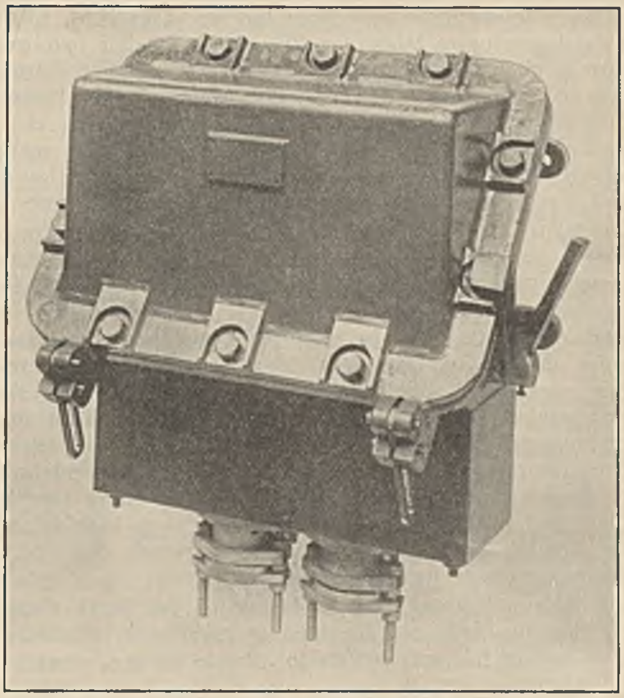


Fig. 8.—Air-Break Circuit Breaker.

Oil-break and Air-break Circuit Breakers.

The oil-immersed circuit breaker is in general use underground on power circuits and has certain definite advantages derived from the oil filling:—

(1) The presence of oil affords an insulating barrier between the arc and any gas that may have accummulated in the air space above the oil level.

(2) The volume of air contained in the circuit breaker case is considerably reduced by the filling of the tank with oil.

(3) The dielectric strength is not lowered after operation of the circuit breaker, as occurs with an air-break.

(4) The cost of the oil immersed circuit breaker is less than the equivalent size of air circuit breaker of similar type.

(5) The oil-immersed circuit breaker can be used for much greater rupturing capacities than the air-break type.

Objection has been taken to the use of oil-immersed circuit breakers on account of the gas which, arising from the contacts as they separate, may accummulate in the air space above the oil. It is doubtful if this is more dangerous than the metallised vapour which fills the large air space inside the air-break circuit breaker after it has opened on a fault. To render such a breaker safe for repeated operation under fault conditions it is necessary to introduce some means of removing this vapour such as an air blast if the breaker is required to operate several times with safety. The kind of duty referred to is that in which it might be necessary to perform when a fault has occurred.

The following extract from the report of H.M. Electrical Inspector of Mines for 1929 shews what is required from a circuit breaker: "Various circuit breakers tripped and were re-closed repeatedly, at first in an attempt to restore the power, and after the arrival of an electrician, in an endeavour to locate the fault. The main switch for the 150 kilowatt generator at bank tripped and was re-closed by the attendant five or six times."

It is of course well known that the gases produced by the arc-energy when the contacts separate under oil are hydrogen and acetylene. These gases when exploded produce pressures of similar magnitude to methane but the pressure rises more rapidly to its maximum value. Oil-immersed circuit breakers are therefore constructed with stronger cases than the air-break. For mining conditions the stronger construction of the oil-immersed gear has its advantages and the danger from the possibility of an explosion of a gaseous mixture in the small space above the oil level is more remote than the risk which attends the repeated tripping of air breaker containing metallised vapour in the space which surrounds the actual contacts.

It is a further point in favour of the break under oil that the hydrogen liberated is effective in absorbing heat and in this way assists to quench the arc.

Until some evidence can be produced from actual tests such as have been made with the oil breakers on the market, that the air-break circuit breaker can be designed to be as safe, as electrically efficient, and as cheap for equivalent ratings, there do not appear to be any grounds for supposing that air circuit breakers can be advantageously used in mining work except on the smaller sizes of apparatus or where only normal load currents have to be broken.

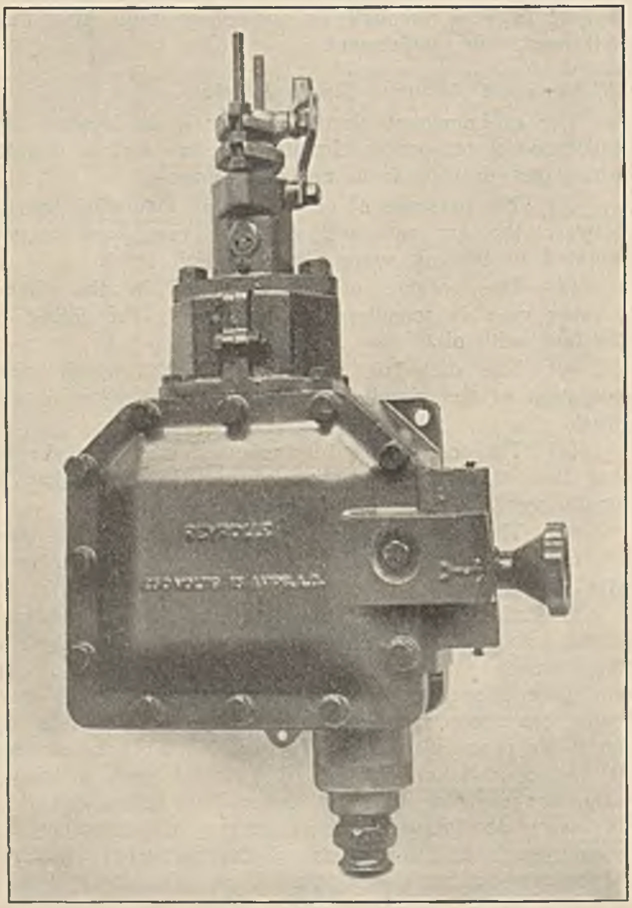


Fig. 9.—A Drill Switch.

The air-break circuit breaker, however, has the merit of requiring no attention to the oil level and there is, therefore, less maintenance because there is no emptying or refilling with oil. That might lead one to suppose that an air insulated mining type transformer would also be preferred but here again for mining transformers above 5 k.v.a. in size, the transformer manufacturers are not able to offer anything except the oil-immersed type.

Summarising the above, the present type of air breaker is used: (1) for small currents; (2) for contactors; (3) where only low rupturing capacity is necessary; and (4) where the number of times the breaker is expected to open faults is known. It is therefore premature to deprecate the oil-immersed type of switch, which has given very good service in the past, until a really reliable air blast circuit breaker is produced.

Earthing of Feeders and Cables.

The report of H.M. Electrical Inspector of Mines for the year 1929 gives a detailed description of typical circuits on which it may be necessary to earth the electrical conductors during examination, tests, or repair. The general conclusion is that in every type of circuit the earthing connection should be made on the switch so that the switch is interposed between the earth and the feeder. The closing of the switch completes the connecting of the feeder to earth.

On the cubicle type of gear extra contacts can be fitted which are connected to earth and arranged so that the isolators can be changed over from the busbar contacts to the earth contacts.

On self-isolating gear the usual practice is to fit extension pieces to the plug-in contacts of the breaker on the feeder side. A further method is to have a special earthing switch which will fit any panel. To earth any one feeder the circuit breaker is removed entirely from the board and replaced with the special earthing switch. Another alternative is to fit each circuit breaker with an interlocked auxiliary earthing switch for use on that circuit breaker alone.

The method of using extension plugs on the circuit breaker contacts (feeder side) is sometimes objected to because of: (1) the time required to place the plugs in position; and (2) the danger of the extension plugs being fitted on the busbar side in error.

Further, this type of earthing arrangement is not possible on all switchgear particularly in cases where: (1) wide current transformer covers are fitted to the switch; (2) where auxiliary switches are fitted to the busbar chambers; and (3) where mechanical interlocks between adjacent circuit breakers on a switchboard are fitted.

It would be of interest to have suggestions as to which is the most convenient method of dealing with this requirement, which now appears to be compulsory. The following is an extract from the report of H.M. Electrical Inspector of Mines for the year 1929: "It is folly to rely upon the assumed correctness of certain switching operations at a distance, and it is entirely contrary to the requirements of General Regulation 131 (g) to work upon conductors that have not been earthed, or adjacent to other conductors that are known to be live."

Multiple Earth Plates.

Under present conditions the earthing of an installation is made by means of an earth plate at bank. With certain fault conditions there will be a difference of potential between the metal enclosure, or apparatus, and the actual earth underground, due to the voltage drop in the armouring which forms the return path for the fault current. It will be seen that when considering the case of a man touching an earthed frame while an earth fault is on it would be an advantage for this particular occurrence if a resistance were included between the neutral point and earth.

Assuming that the armour only has 50% conductivity of a conductor with a resistance of 1 ohm, then instead of the voltage being two-thirds of say 260 volts, (170) at the apparatus, where the earth fault is on, with the addition of a two ohm resistance, the voltage would be two-fifths of 260 volts (104).

If the man touches one live phase with an earth fault on, the resistance of the man is so high relatively to the earthing resistance that the potential drop across the latter is negligible.

The conclusion is, therefore, that for a man touching one live phase of the system there would be little or no advantage in an earthing resistance. But there is an advantage to the man in the case of touching the metal frame which has become alive through a fault from a conductor to the frame.

It may be as well to point out that it is necessary to provide an earthing resistance capable of passing more than the required current to trip the earth leakage protective devices.

To make the ordinary earthing system safe it would be necessary to bond all rails, pipes, and other material to earth plates at multiple points so as to ensure that all material is at the same potential as the nearest portion of the earthing system.

It would be preferable to provide multiple earth plates rather than one earth plate at bank so that the potential of the bonded rails etc., were at the same potential as the surrounding earth. The difficulty of carrying this out in a mine is considered to be too great and the maintenance of the bonding would be impossible under present conditions.

There is no doubt that the multiple earth plates, if it were possible to maintain them, would add to the security of a system as regards accidents to the personnel if the system also were protected with earth leakage protection with a resistance inserted in the neutral point connection to earth.

Discussion.

Mr. C. C. HIGGENS, Chairman, said he was rather surprised at the phenomena which Mr. Grover had mentioned in regard to trip coils, as he was not aware they were anything like so complicated. With respect to standardisation, Mr. Grover had introduced an interesting and forceful analogy between electricity, air and gas: it was a very important point and shewed that electrical people had erred very much in not standardising sufficiently. He would like to see every motor standardised and certainly considered that for "flit plugs" standardisation was essential.

Judging from the industrious penning of notes which he had observed when Mr. Grover weighed the case for air-break versus oil-immersed gear, Mr. Higgens anticipated a lively debate on that vexed question.

It was unfortunate that, owing to the breakdown of the lantern, they had not been able to see Mr. Grover's slides, but, on the other hand, they were fortunate in having had the opportunity of seeing some of the actual gear that afternoon whilst visiting the Barnsley Main Colliery. Mr. Higgens expressed their keen appreciation of that inspection, which had been of especial interest in view of the question which Mr. Horsley had recently raised respecting earthing. It had been a very interesting experience.

Mr. WILLIAMS said he had found very much of close personal interest in Mr. Grover's paper. The remarks concerning oil-immersed switchgear were worthy of serious attention: many people had recently been endeavouring to force the use of air-break gear in collieries. Regarding the question of plugs, the standard plug had not made the rapid progress which it merited, but that was perhaps because it came along too late in the day. Mr. Williams agreed with the opinion expressed by Mr. Higgens that thermal overload protection was coming very much to the fore, and he considered it to have great advantages. He could not agree with Mr. Grover in regard to inserting a resistance in the neutral.

Mr. J. MANN raised the point that in the type of gear seen that day there did not appear to be the opportunity for installing trip coils fitted with time limit fuses. He believed it was usual on that type of gear to fit the oil-immersed dash-pot type, but had found that these time limits did not work out quite so definitely one as was led to expect. For instance, Mr. Grover had said that certain switches may be set to operate in predetermined sequence. But it was quite possible that one was in a cold situation and the one fitted previous to that was in a warm situation, with the result that the setting may be higher at the first switch. It actually tripped at the same time as, or before, the second one, which should be at a lower setting.

Mr. Mann was in full accord with all Mr. Grover had said about "flit plugs" on smaller gear. When it is a case of connecting sealing boxes, etc. and putting a "flit plug" with its attendant connecting box a little distance away, considerable cost would come into account; that might be a serious and restricting objection. It would be found that the cost of this little arrangement would be about £10 as against a normal cost of £3 for the "flit plug" fitted direct on the switch in question.

In regard to the preference for oil or air break gear, Mr. Mann largely agreed with Mr. Grover. Whilst fully accepting the case for oil-immersed gear, he thought there was a field for air-break gear in the smaller gear (and that particularly for conveyors) at the face. His preference was principally due to the ease of maintenance of the air-break type, no attention having to be given as in the oil-immersed gear to the oil level, etc.

With regard to Mr. Grover's remarks respecting 5% tripping, Mr. Mann believed it was hardly possibly to make leakage protection gear suitable for working at 5%, when one had to get down to such small sizes as were in use in conveyors.

The question of the resetting of leakage protective gear had been very prominently brought to their notice at the collieries recently by the Inspectors, due, no doubt, to the accidents which had recently happened because switches which had been automatically tripped due to leakage, had been re-closed by unauthorised persons.

In his own case Mr. Mann had fitted a cover to the resetting device and tripping device, which was embodied in one, which very largely resembled the original cover, with the exception that there was a set screw that could only be taken out by a special spanner. The entry was at the front by means of a relatively long path, and a key of special design had to be inserted to operate the setting device.

Mr. Mann then referred to multiple earthing, and said that it was of course to have one earthing system at the surface of the mine, but it was quite within bounds, and he might say good practice, to earth at as many other points as possible along the armouring. For example with a pump, earth the armouring in the sump.

Mr. FOSTER.—With regard to the earthing of the apparatus in the mine, said he considered the figure of 50% which Mr. Grover had taken was too low.

Mr. WATSON-SMITH remarked that the manufacturer of switches was doing away as far as possible with the use of cast iron: cast iron had been a source of much trouble in the past; it had not been able to stand the heavy knocking about which machinery had to undergo underground. The older type of switchgear was designed not so much for use underground as for use at the surface: electrical plant of to-day had got to do duties both in regard to capacity and environment which were entirely unthought of a few years ago.

Mr. GROVER.—Mr. Williams had raised the point about inserting resistances in the neutral point. It was undesirable to insert a large resistance and, of course, if the system be completely insulated, earth leakage protection could not be used. There was, however, this advantage of earthing through a low resistance that it undoubtedly helped in reducing the severity of the shock to the man who may chance to touch a faulty piece of apparatus.

It was most desirable that there should be a standard "flit plug" to fit all switchgear, but the difficulty was to design one which would fit all makes of apparatus.

Doubt had been expressed by Mr. Mann as to whether the figure of 5% leakage trip was not too low, but it was possible to obtain this figure on certain sizes of current transformers and relays.

The locking of the cover described by Mr. Mann was similar to that mentioned by Mr. Grover—it consisted of a set screw and spanner.

Mr. Grover could but agree that it was excellent practice to earth in the sump, but most pumps were already earthed in the sump, the frame of the pump probably being earthed through the water. The earth round the coalcutter is not all at the same potential, and it was not possible to have multiple earth plates all over the pit.

Mr. MANN mentioned that he had only put forward the pump as an instance: he intended to infer that an installation should be earthed at as many points as possible.

Mr. GROVER.—With respect to earth plates, the bonding of the rails etc. was not practicable. Multiple earthing rather tended to fail in giving the perfect security because there was so much apparatus that could not be bonded.

Referring further to the position of the trip coil Mr. Grover said he wished it to be in such a position that a fault in the auxiliary did not become a busbar fault, so that the opening of the circuit by the circuit breaker removed the fault from the busbar site where the busbar fault was very serious and might result in the closing down of the whole installation.

Mr. Grover agreed with Mr. Foster that the conductivity should be above 50%: in some cases he had come across conductivities as high as 200% or 300%. At present the Mining Department only asked for 50%, which he thought was too low, although it should be noted that figure is given as the compulsory minimum.

DONCASTER SUB-BRANCH.

Notes on Breakdowns.

T. H. WILLIAMS.
(MEMBER)

(*Paper read 28th March,* 1931.)

It is generally realised that electrical apparatus of all machinery used in mining, is in some respects, delicate owing to the fact that it is dependent on insulating materials which are mechanically weak, and that it sometimes embodies complicated arrangements of springs, toggles, levers, etc. To which inherent frailty there must be added the rough usage which is meted out by the human element. So in introducing a paper under this title it will not be out of place to acknowledge the credit due to designers, manufacturers, electrical staffs and last, but not least, the Association of Mining Electrical Engineers, that mining electrical plants are maintained in the safe and efficient manner that most of these installations are to-day.

Despite thorough examinations and tests, breakdowns still occur occasionally, and it is one of the objects of this paper, to analyse the faults which arise, with a view to ascertaining how far it is possible to reduce their number. As breakdowns are to be considered, it may be desirable to specify what constitutes a breakdown. Doubtless, a fair discussion could rage round this point, but the author proposes to adopt the following definition: "A breakdown is a failure of electrical apparatus whether it interferes with the output or not." This is introduced so as to provide a base for comparison, as some years ago wonderful figures were published, in our Transactions: but, as they only counted stoppages which resulted in loss of output, this obviously eliminated most of the breakdowns on pump motors etc., and the figures were thus of little or no value for the purpose of studying the comparative percentage of breakdowns between one colliery and another. It is not intended to suggest that real comparison is possible, for as is well known, the condition and duties of electrical plants at collieries vary tremendously.

The causes of breakdowns are so varied that they could be divided and sub-divided under many headings, but to simplify matters it is proposed to consider them under four main headings, viz.:

1. Faults in manufacture, material or design.
2. Faults caused by natural conditions, falls of roof, water, etc.
3. Faults caused by overloading and vibration.
4. Faults caused by the human element.

The chart Table I. shews the number of breakdowns and the percentages attributed to various causes at two collieries (A and B) during a period of twelve months. These figures are abstracted from the daily reports, and though in the case of colliery A they may appear alarmingly high, it must be borne in mind that *all* stoppages are recorded and that many of them are trivial. As a matter of comparison, it may be noted that an Insurance Company's report states that switchgear was responsible for 28.9% of their breakdowns, but as their breakdowns only average 1 in 7 of motors insured, it is assumed that only serious breakdowns were tabulated, and therefore the comparison is only approximate. It is often difficult to assign the true cause of a breakdown, but every effort has been made to ascertain the facts, and the figures may be considered as accurate as it is possible for them to be.

TABLE I.

Particulars of Breakdowns.

	Colliery A.	Colliery B.
Surface Motors	12 = 322 h.p.	29 = 1062 h.p.
Underground Motors	35 = 1856 h.p.	19 = 2174 h.p.
Total	47 = 2178 h.p.	48 = 3236 h.p.
Breakdowns due to		
Design or Material	74 = 49.0%	13 = 33.3%
Falls, Water, etc.	40 = 26.4%	8 = 20.5%
Overloading, etc.	22 = 14.5%	8 = 20.5%
Human Element	15 = 10.1%	10 = 25.7%
Parts affected		
Motors	36 = 23.8%	11 = 28.2%
Switchgear	86 = 56.9%	20 = 51.3%
Cables	29 = 19.3%	8 = 20.5%
Cutters and Trailers	51.6% of total	30.0% of total

Faults in Manufacture, Material, or Design.

It will be conceded that so far as principles of design are concerned, most mining electrical engineers do not consider themselves competent to criticise; but, in any case, it would appear doubtful whether there are many grounds for complaint, providing always that a reasonable price is paid, and the manufacturer is informed of the conditions under which the gear has to work. It is a matter of considerable importance that the manufacturer be given details regarding unusual temperature or other adverse conditions, and if this is done there is little doubt that the plant will meet requirements and do its work satisfactorily. The mining electrical engineer is, however, more deeply concerned than this, for he not only has to instal the right kind and quality of plant but he has to maintain it in first class condition; and it is in that direction that he often becomes sarcastic at the expense of the designer.

It would take many evenings to discuss in detail all the defects, large and small, which have been discovered at one time or another, and the point is only brought forward for the purpose of drawing the designer's attention to the desirability, that he should personally assemble and dismantle new gear before it is put on the market. For the ultimate benefit of colliery electrical staffs, the work should be carried out under pit conditions, viz.: poor light, in restricted space with limited tools, and unskilled assistance. To make the test complete, it should be carried out in a tearing hurry, equivalent to the speed the electrician has to develop when the pit work is at a standstill, due to a breakdown.

The question of design cannot be left without drawing attention to one or two common weaknesses which, though small in themselves, cause considerable trouble. The chief of these is the use of the taper pins for securing the handles etc., of starting gear.

Another is the fitting of ball bearings. Granted, that many ball and roller bearings are easy to fit, to withdraw them is another matter, and one might easily imagine that the designer never contemplated the possibility of a bearing failing. In one or two well-known makes, it is an exceedingly difficult matter to draw a bearing off the shaft, particularly where a fan is fitted. Incidentally, the fan itself is often a badly designed and weakly fitted affair. Regarding the remedy for this state of affairs, as it is extremely improbable that the designers will carry out the programme of dismantling and reerection outlined above, the next best thing is for all users to complain in language forcible but polite, in the hope that we may convince the manufacturers that alterations are necessary.

Defective Material.

Though large sums of money are spent each year on experimental and research work, and great improvements are evident, it is unfortunate that in practice we find failures of material not infrequent; but as even the largest manufacturers are dependent to some extent on outside sources, for semi-manufactured or even finished components, it will probably be suggested that the outsiders are at fault. Prompt complaints will therefore often enable faulty batches of material to be located and withdrawn before the majority of the gear reaches the hands of the consumer.

Springs of all kinds which are so essential for the operation of switchgear, etc., are particularly liable to fail and, as many of the failures are definitely due to faulty material and not misuse, it would appear that it is necessary to test springs under more severe conditions than has hitherto been the practice.

A more serious indictment against manufacturers regarding material is that, despite the use of templates and jigs, it is found impossible for the user to be confident that spare parts will fit. This applies to large as well as small articles, including motor end shields, controller contacts and other numerous articles which are kept in stock. Even the holding down bolt holes, and shaft centres are found to vary on so called duplicate motors, and though this may appear a small matter, as far as the manufacturers are concerned, it is a serious matter for the engineer. The latter probably had considerable difficulty in convincing the powers-that-be that duplicate motors were essential, even though they cost more. It is therefore particularly annoying when the general manager has to be informed that instead of the standby motor being put to work in about half an hour, it has taken two or three hours longer, because holes had to be drilled out or packing put under the feet.

Part of the manufacturers' system of inspection, storage, or despatch, is at fault, as complaints are made that many small parts ordered for replacement do not conform to the specified requirements, though every effort is made to supply full details as per nameplate etc. To style any criticism which may arise from the manufacturers' side that the ordering is at fault, it may be said that on some occasions the wrong parts have arrived even when a sample has been enclosed with the order, and more extraordinary still, the sample has been returned along with the dissimilar parts!

If a suggestion may be offered to manufacturers, it is that they consider the question of stamping or casting numbers on each part to enable the engineer to order with confidence duplicate spare parts. It is true, a drawing of the required part would often obviate these difficulties, but in some cases the cost of the drawing would exceed the cost of the article. It is readily acknowledged that the question of numbering parts is a difficult one, as they run into thousands of items; on the other hand, it is not easy for the electrical staff to get full particulars of a small part, say, on a switch mechanism, particularly if it is about a mile inbye. In fact, it may be necessary to dismantle 50% of the mechanism to obtain the dimensions of a small part which might be shewing signs of wear; whereas, if the parts were numbered and catalogued, it would be a simple matter to order replacements. Some manufacturers, of course, do this but they appear to be in the minority; and, for the information of the others, it can be indicated as obvious that many more spare parts would be purchased and kept in stock if they were easy to order.

Whilst on the subject of numbering, some manufacturers' nameplates are of no value at all after a few months in a damp mine ; in fact, some of them are hardly decipherable when new, and appear as if the youngest member of the staff had done his worst. It has often been suggested, and the author believes been adopted by the B.E.S.A., that nameplates should include certain minimum information in regard to ratings and characteristics, such as rotor voltage, if a slipring machine ; information of this kind is valuable at many small collieries where the testing equipment consists of a megger and very little else.

Reverting to the chart, Fig. 1, it will be seen that in the collieries under review 49% and 33% respectively are attributed to manufacturing defects of material or design. The majority of these were on switchgear—which is not surprising, considering the multiplicity of small and delicate parts involved—only a small portion —were on motors, but no failures of cables are reported under this heading, which is, incidentally, a solid tribute to the excellent work turned out by the cable makers.

The figures are fairly high, and it may seem that proof is required that the manufacturers failed to this extent ; it is to their credit that in most cases where it was considered they were at fault they admitted liability. In defence of the makers, let it be stated that the conditions at colliery A were particularly severe, and that the apparatus had to meet much severer conditions than were probably anticipated by the designer. To prevent any misunderstandig, it should be made clear that more than fifty per cent. of the defects were on one particular type of gear, and efforts have been made by the firm concerned to remedy the defects, which were chiefly broken pins and springs on air-break switchgear.

For those who are interested in the controversy, air-break v. oil-immersed switchgear, it must be said that failures are much more prevalent on air-break gear ; on the other hand, that is the class of gear generally selected for use in the worst places, viz. : nearest the coal face, and, therefore, it has the heaviest duty to perform.

Though the manufacturers may appear to have had allotted to them a considerable amount of the blame as regards breakdowns, it must not be imagined that their products are badly made ; on the contrary, the plant generally is good ; the weaknesses are evident only in detail. There is no doubt that when the manufacturers are informed of defects, they will make every effort to remedy them, as they are at all times anxious to give satisfactory service.

Falls of Roof, Water, etc.

It is inevitable that the natural conditions underground should be directly responsible for a proportion of breakdowns, and it is to be expected that this proportion might tend to increase, owing to the development of machine mining, as this entails apparatus being installed adjacent to the coal face ; which is obviously the most dangerous part of a mine.

Falls of roof create a lot of trouble where machine mining is carried out on an extensive scale, for it is found that gate-end switchgear, gate cables and trailing cables are often damaged by this cause ; luck appears to play a large part, for it will be found that whereas 20 tons of roof have fallen on one cable, no damage is evident ; on the other hand, a piece weighing about a cwt. dropped on to a cable which happens to lie across a rail may damage it considerably. Trailing cables are often damaged by falls, and it is fortunate that in most cases the damage is trivial.

One of electricity's greatest enemies is, of course, water ; this is often met with underground, and in many mines there is the ever-present danger of an inrush of water drowning the motors and switchgear, whilst in many more there is constant trouble due to water falling from the roof ; also in nearly all mines condensation in one form or another has to be contended with. Not only is water an evil in its free state, but when confined in pipes it is also dangerous ; for a failure of a pipe, a joint, or the leakage at a sealing gland of a pump may seriously damage electrical equipment.

Steep gradients often mean runaway tubs, and it is no easy matter to protect cables from damage when this happens ; a minor risk is that of derailed tubs and smash-ups.

At the collieries A and B the breakdowns caused by what may be termed natural causes were 26.4% and 20%, respectively, some of which were due to sudden inrushes of water, which drowned the motor and switchgear, in other cases faults arose through condensation inside totally enclosed motors ; cases have arisen where it was doubtful whether the water was due to condensation or whether water actually percolated through the flameproof joints on the machines, and as a preventive, the joints on starter covers have been made with thick grease, whilst a red lead mixture has been used on the permanent joints of the machines.

Water has been found in the interior of totally enclosed flame-tight motors after they have been under water, presumably it had entered via the bearings. In the majority of cases where motors have been under water, it has been found possible to dry them out and they have subsequently given satisfactory service. Generally, they have only been in water a few hours ; this remark applies also to 3000 volt protected type motors.

It will be realised that under wet conditions the trailing cables are subjected to severe tests, for it is impossible to prevent water passing through small cuts in the cab tyre sheath and attacking the ferflex ; it is also difficult to keep the pummels dry. The water is by no means pure and, therefore, it is essential to deal quickly with all cuts, though it is difficult to locate them underground, as the cable is so wet and dirty. The type of cable in use at the collieries A and B is composed of three power cores, one earth, one pilot core in the centre, with an outer ferflex sheath, surrounded by a layer of cab tyre. It is therefore a heavy trailer and it is expensive. The owners and management of the particular collieries under review, realising the arduous conditions, have always bought the best possible cable and switchgear, to ensure safety, and it is a happy fact that it has proved money well spent.

It will be obvious that all the minor cuts discovered on the cables during periodical surface inspection, were not classed as breakdowns, but all damage done to cables by heavy falls of roof are included, the total being seventeen.

Runaway tubs were responsible for several serious breakdowns at colliery A as the H.T. cables were damaged ; and, as sufficient slack was not always available, it sometimes meant installing two joint boxes with a short length of cable between This trouble is fairly common on steep gradients, and in one drift the problem became so acute that the cable was transferred to another roadway. Where this is impossible, attempts have been made to guard against the evil, by laying the cable at the side of the roadway and covering it with loose dirt. Unfortunately this is not always possible, as where water is present in the mine, it may find its way to the cable, and the cure possibly prove to be worse than the disease. Nature is difficult to combat, and foresight should be used when installing plant at mines where these difficult conditions have to be met.

Overloading and Vibration.

Though overloading is fairly common and vibration is not unknown on large gears, these evils are probably greatest on small haulages of the direct driven type, fitted with a rawhide pinion but minus a flexible coupling. These gears, being semi-portable, are often moved; therefore a concrete foundation is not considered necessary, and, sooner or later, vibration develops, followed by breakdowns on the electrical side. Absence of a proper foundation is not the only cause of vibration; other causes may be play in bearings, wear on gear wheels or rawhide pinions. The electrical parts most commonly affected are the rotor conductors, the slot insulation being disintegrated by the continual jarring, the ultimate result being a short circuit or an earth. Sliprings also suffer, brush wear is rapid, and the rod connections to the rings often breaks; the outside one, i.e., the longest rod, breaking most frequently. Vibration has become so severe on some of these gears that oil rings have jumped from their grooves followed by the seizure of the bearings. In such cases, the remedy is obvious, but it is not always easy to apply.

Vibration on motors directly coupled to centrifugal pumps may be due to out of balance or partly choked impellers, and wear on the pump bearings quickly makes itself evident—to the electrical man.

The question of overloading is difficult to deal with, and as it concerns the human element will perhaps be better dealt with later under that heading. The recent development of thermal overload protective devices provides the engineer with a more effective safeguard than the ordinary solenoid types. As is generally known, the latter types, even when fitted with time lags, do not adequately protect the motor, for with most of them it is possible for an overload to develop slowly and to increase to, say, 30% overload without tripping the breaker. The thermal types can now be obtained to work at very close settings, and as it is the final temperature of the motor which matters, these types are theoretically and practically correct and will probably become standard in a few years' time.

At collieries A and B the troubles under the heading "Overloading and Vibration" were 14.5 per cent. and 20.5 per cent., respectively; the defects on rotors caused by vibration were the most common, followed by slipring trouble. Overloading was responsible for one motor being burnt out, and several resistance grids were damaged by the same cause. Loose connections on busbars were responsible for two stoppages, and these are attributed to vibration, as lock nuts were omitted when the gear was assembled. The moral is obvious. Regarding vibration, it may be said that a large percentage of it arises from the mechanical side of the equipment, and if systematic inspection and maintenance were efficiently carried out on mechanical gear it would be beneficial to all concerned.

The Human Element.

A far abler pen than the author wields would be required to do justice to the problems appertaining to the human element. In fact, it would appear that there are problems worthy of study by the psychologist regarding the working of man's mind when he is confronted with the realisation of nature's power, the darkness, the limited range, not only of vision but of space, which are met with underground. If the mind of man does not react, consciously or sub-consciously, to these conditions, it is difficult to account for the things that are done, for most of those who read these notes will be able to give instances of working behaviour which would appear ridiculous if carried out in the light of day. The attitude of many colliery officials towards overloading may be quoted as an example of how the mind works when men are underground, for though they pay lip service to the question, and agree that it is unwise, in practice they very frequently encourage it. Presumably, they work on the proviso that "What breaks one will buy another." Whilst there may be some justification for that point of view on an odd occasion or so, it is surely neither an efficient nor sensible principle to adopt as a standard.

The peculiar thing is, that whilst at times a haulage is overloaded to such an extent that it is impossible for it to work, yet at other periods of the shift it may be standing idle. The general attitude of underground workers appears to be, that an engine is (whether large or small) extremely powerful, if it is designed and installed to pull twenty tubs up a gradient, and it does this easily; it is not long before some enthusiastic, but ignorant official says—"put twenty-two on for a time or two whilst we get rid of this coal." Twenty-two thus becomes the standard load for the haulage, till another emergency arises, when the number is increased to twenty-four, which in turn becomes the standard, this increment continues till either the gear or the motor gives up the unequal struggle; and then comes another report reading "Output lost due to electrical breakdown."

That state of affairs is quite common, and so are overloads due to lack of pulleys, allowing the rope to cut its way into sleepers, and to run continually in water and dirt. Will any useful purpose be served by enumerating these well known evils? Surely in these modern days the engineer ought to have the assistance of all the underground officials in his efforts to obtain maximum efficiency.

It is a curious thing, that though underground officials will persist in sending untrained and unskilled men to drive haulage gears, work coalcutters, etc., they are the men who would shudder at the very thought of sending the same men to drive their motor cars. There is really no difference, unless it be that the machinery in one case is their own and in the other it is not. Sand buckets have a nasty knack of disappearing, and one is told that the Deputy has sent a man for one; would the Deputy take away a fire extinguisher attached to a building owned by him? It is doubtful. By the way, a remedy for fire buckets being used for other than their legitimate purposes is to use the type provided with a semi-circular base, fitted with a handle. Most mining electrical men are familiar with this type of trouble which, though serious, eventually becomes commonplace and is accepted as inevitable. The annoying part of it is, that it is not always lack of intelligence; sometimes it is misplaced ingenuity, such as that shewn by the Deputy who hung a sand bucket on an auto-transformer starter handle to retain it in the start position. His idea was to run the pump for longer periods without attention: needless to say he was unsuccessful.

As an endeavour is being made to suggest a remedy where an evil is pointed out, it is suggested that many of the troubles on underground gear would be rectified if the men engaged on electrically driven haulage gears, pumps, coalcutters, etc., were directly under the control of the electrical engineer. It is admittedly a contentious question but experience of the method has proved that it works satisfactorily. The mode of operation is that a man, after being considered suitable by the electrical engineer, was engaged for a period as a labourer in the electrical department ; during that time he learned to distinguish the various parts and saw the effects of misuse, breakdowns, etc. Later he travelled round the pit with the shift electrician on inspection and maintenance, and by this means became aware of the location of switchgear, haulages, etc. During slack periods he would spend a day with a haulage driver, and eventually he became competent to drive practically any of the gears, pumps, etc., in the pit. Another great advantage was that this type of trained man was able not only to handle the gear efficiently, but in the event of a breakdown was able to telephone an intelligent report giving details of the trouble.

It is extraordinary, the type of message which reaches the electrical department regarding breakdowns underground, rarely is the defective part named ; it is generally, the motor wont go on such and such a gear, and it is not uncommon to find that it is a mechanical fault which is overloading the motor. Incidentally, the electrical end of anything is generally looked at with grave suspicion when any abnormal conditions arise, and it is an exceedingly difficult matter to convince people that the motor is in good order and that the fault is elsewhere. This problem arises most frequently where centrifugal pumps and conveyors are concerned, though it is not unknown on other types of gear. The suspicion is bred by ignorance and electrical plant would indeed be weird and wonderful if it could accomplish some of the things that exist in the imagination of the ordinary underground worker.

Having discussed at some length the sins of commission and omission of other workers, it will be well to turn for a moment to a study of the human side of the electrical staff. There is, in some cases, a danger that the electrical men may come to consider that a pit is run for the electrical side and that everything is subordinate to them. The truth is, of course, that the electrical plant is merely a useful servant and is of secondary importance to the "getting of coal." The electrical men, therefore, exist for the purpose of assisting in the main object, and, though high ideals are very admirable things in their way, they must not let their enthusiasm carry them away to such an extent that they introduce gadgets or methods which are not essential to safety and the economical production of coal. For instance, the author once visited a colliery and found that the number of spare motors in stock was almost equal to the number in use. It is certainly desirable ot provide reasonable safeguards against emergencies, but that can be done at too great a cost. It is suggested that there is scope for a full consideration of the costs, probable loss caused by breakdowns, amount of money lost by plant lying idle, depreciation, etc., before embarking on the purchase of a large quantity of spare motors, and other electrical plant and details. The question of spares depends to a great extent on a man's temperament, for whilst one engineer would not be comfortable unless he had spares for every important motor, another would be quite happy as long as he had a spare for, say, his fan motor.

As stated previously, it is not an easy matter to state definitely the why and wherefore of a breakdown, but at the collieries A and B it was judged that the figures due to the human element were, respectively, 15% and 20%. These figures only apply to the direct failure of the human element (and do not include indirect causes such as overloading, which are, of course, the result of human action). and they include not only the failures due to neglect on the part of the electrical staff, but to those of the machine attendants as regards burnt controller contacts ; neglect of trailing cables, and bad contacts on switchgear due to misuse.

Typical failures of the human element were, the connecting up of an earth core instead of a power core in a trailer, and a faulty connection on a busbar caused by the absence of lock nuts, which should have been fitted by the electrician.

It will be seen, therefore, that the electrical staffs have carried out their duties diligently and well, for very few failures were preventible : which is, after all, the test of maintenance for though breakdowns are, as has been pointed out, due to varied causes the electrical staff cannot be blamed for any which are beyond their control.

Conclusion.

Though an attempt has been made to compare the breakdowns at collieries A and B, it is not advocated that comparisons as made between collieries shall be considered as final or conclusive, as conditions vary to such an extent as to make it practically impossible. The fact that may be stressed is the value of recording breakdowns with a view to analysing each one and, if possible, applying a remedy, or removing a defect to prevent a recurrence. Also not to hesitate to complain to the manufacturer if it is considered that he is at fault.

There is a lesson to be learned from every breakdown, for a fault which occurs on one gear is an indication that the part should be particularly examined on all similar gear. The most trivial things often prove a guide to the solution of some problem and no one should be content to accept a breakdown without sifting out the cause and forming some theory as to how it occurred. In many cases, the source of the trouble is obvious : but a little reasoning power, seasoned with technical knowledge, will generally solve what may appear at first to be a first class mystery. Judicious questioning of individuals generally results in some clue, but a hint may be given that it is wisest to check the essential facts and not rely on second hand information which, despite all the goodwill possible, is apt to be misleading. It rests with the men who are inspecting, testing and maintaining the plant to reduce the number of breakdowns, and they can do this by observing things. Many people see things, but few observe them, and the electrical man who is inspecting plant, particularly underground, must have a keen eye for detail, together with a good sense of smell. He should at all times be observant, for instance, he should keep an eye on the cable, as he travels an underground roadway, this sounds trivial but it is not always done ; he should be alert to the value of insulation tests, under various conditions ; and so one could go on indefinitely, but it all comes back to the one fact, that he should *always* be examining and noting any change in the conditions, however slight they may be. It is a good plan to have special times for examining different parts : for instance, one week special attention could be paid to, say, all connections, and they could be tried with a spanner ; another week, say, overload coils could be thoroughly examined, and so on ; this, of course, is in addition to the general routine examination, as it is not generally possible during the latter to make the desirable thorough examination of all parts, as time will not allow.

The author wishes to thank Mr. Watson-Smith, General Manager of the collieries dealt with in the paper, for allowing the use of the information given herein.

INTERESTING BREAKDOWNS.

A few interesting breakdowns with which the author has had to deal at various times during his colliery experience may prove interesting. The following notes give an outline of the main facts in each case.

Example 1.

An old bi-polar d.c. motor driving a screening plant was reported to be smoking. On examination no fault could be discovered, an insulation test was O.K. and the bearings and air gap appeared in good condition. Another attempt was made to get the motor away but smoke again appeared before it reached full speed. As the pit was idle it was decided to remove the armature with a view to thorough examination. The pedestals and bearings were removed and when a man took hold of the shaft to lift one end of the armature, part of the shaft came away in his hand. The smoking was caused by the magnetic field pulling the armature across so that it fouled the pole shoe ; when the current was switched off, the armature fell back into a central position and hence the preliminary indication of a proper air gap.

Example 2.

In the days of single core unarmoured cables underground it was reported that one of the cables feeding a 10 h.p. d.c. motor on a small ram pump, had burnt through—not an infrequent event in those days as leakage across wet props, etc., was very common. On inquiry it was stated that the pump was still running, and some confusion arose until it was discovered that the motor was actually running with the broken ends of the cable lying in water.

Example 3.

A new plant was being installed at a large colliery and it fell to the author's lot to take charge of it shortly after two parallel shaft feeders had been installed but not put into service. When the time came for phasing out the two cables it was found impossible to do this, as there was a short on one of the cables. The cable makers who had supervised the installation of the shaft cables were communicated with: meanwhile a thorough examination and tests were made, and it was thought that the fault was at a certain point in the shaft. This was confirmed by the cable makers' representative with his more elaborate testing gear. It was decided to cut the cable adjacent to the spot ; when this had been done an insulation test was made, and to the consternation of the people concerned, the cable tested O.K. in every way. The portion containing the calculated position of the fault was cut out, and a full enquiry made into the history of its installation.

Evidence was obtained that the cable had slipped off the pulley at the mouth of the shaft owing to the loco (by means of which the cable was being lowered into the shaft) being unable to hold the weight on the greasy rails. The cable falling off the pulley was apparently the cause of the fault, as it fell across a beam and it is presumed this caused a twisting movement thus putting a short on the cores. When the cable was cut, the twist came out of the cable with the result that the test was good. The defective portion was returned to the makers' works, but no further report was secured, and as the makers installed a new cable no demand could be made for any particulars. It may be stated that there was little sign of damage externally on the cable.

Example 4.

Another interesting shaft cable fault was caused by a tramload of pit rails being accidently tipped up at the pit top with the result that all the rails went into the shaft. There were two cables in parallel in the shaft and as both the H.T. switches came out, it was obvious that one if not both cables were damaged. This happened at midnight and as there was only one shaft at this particular pit (the other one being at another pit about two miles away) the position was serious. The author tried to get into the shaft to see what damage had been done but found it impossible owing to the number of rails which had become lodged in the sides of the shaft and which had to be removed before the cage could pass. Insulation tests were made on the cables and it was found that one was down, but that the main feeder tested O.K. Fortunately there was an electrician down the pit, so instructions were given for all switches to be opened and power was put on this cable. Then the electrician was told to resume the supply of power via the interconnecting cable, incidentally he had no means of testing the insulation, etc., but as the switch held in everything was considered satisfactory.

After the shaft had been cleared the cables were examined and it was seen that the second feeder had been struck by a rail at one point. As it was essential that the pit should start work, this place was taped up to prevent the entry of water, as the bottom end of the shaft was very wet. No sign of damage could be seen on the interconnecting cable. The men rode the shaft but after coal winding had been in progress a few minutes several switches were reported to have tripped. The interconnecting cable, which it will be recollected had not been tested since the rails went down, was tested with a "Megger," the insulation test was 100 megohms, so the switch at the shaft bottom was closed, a man being placed in a position so that he could see into the shaft. The switch came out immediately and the man reported a flash which on examination was found at another point on the cable. It will be remembered that power had been on this cable for some time and it was difficult to account for this fault, considering the good insulation test. The explanation appears to be as follows ; the cable had been damaged by the falling rails, the cores being exposed. During the overhaul of the shaft and the winding of men at reduced speed, the cable stood up alright, but immediately coal winding was started the water was splashed on to the exposed cores ; the resulting flash over dried out the moisture, giving the high insulation test. The resumption of coal winding again splashed water on to the cable. The position of the fault was peculiar; the cable was an old one, the armouring shewing signs of corrosion and so it was decided to scrap it and install a new one in the adjoining staple shaft. The top length with the fault a few yards from the mouthing, was dealt with by lowering about eight yards of cable which fortunately happened to be available at the pit top, and installing a joint box inside the seam.

Example 5.

Another interesting problem, though not a breakdown, was the coupling of two induction motors to run together when solidly connected to the drive. The problem arose at a busy period and not much thought was given to it, it being assumed to be simply a question of connecting the rotor leads in parallel to a liquid starter. The man doing the work reported difficulties and a little reflection shewed that the rotors should have been phased out, but as this meant that the couplings would have to be drilled, etc., and time was precious, temporary connections were made as shewn on the sketch. This worked so satisfactorily that it was several weeks before the work was done. It may interest some of the members to see how this problem was dealt with though there is nothing extraordinary about it.

Example 6.

The breaking of a joint on the delivery side of a centrifugal pump flooded an old type four pole slow speed motor. Attempts were made to dry out the field coils and armature but it was found that the insulation had perished and that a complete rewind was necessary to make the motor reliable again. The whole of the circumstances were fully considered, the cost of material and labour for a rewind, the values of scrap copper and metal were estimated, and prices obtained for a modern second hand motor. The conclusion was reached that the latter would be slightly cheaper in first cost and would prove a more reliable machine, as commutation had never been really good on the old motor. The second hand machine was adopted with satisfactory results ; the moral, of course, being that the obvious steps of making repairs are not always best.

Example 7.

A liquid starter on a 300 h.p. synchronous motor was reported to be flashing badly when the motor was started, no matter what grade of solution was used. It was found that the pit water was too good a conductor. Water out of the town main was tried with the same result, so condensed water was used, with the addition of a little soda, and note was made of the quantity used for future reference. This cured the trouble and it also reduced the flashing over on the sliprings, which previously had frequently occurred when starting up. This is mentioned as it is not often necessary to use condensed water in liquid starters.

Example 8.

A 15 h.p. slipring motor which had been doing about normal load on a three throw ram pump was under water for several days and a complete rewind was necessary. This was done at the colliery, the wire and method of connection being as before. A 12 h.p. motor on a haulage was found to be overloaded so it was replaced by the 15 h.p. motor, but to everyone's surprise the latter would not do even as much as the 12 h.p. It started up alright on the first two or three notches but as the load increased the speed fell away and when the current was about 20% above normal the motor stalled. Resistances, controller and conductor tests were taken, and as these appeared alright, it was thought that voltage drop might be the cause, so this was checked. The 12 h.p. motor was replaced, the 15 h.p. machine brought to bank and a test made of the rotor voltage shewed it to be much lower than it should have been, so the stator was reconnected in mesh instead of star. It was later ascertained that some years previously it had been rewound by an outside firm, and either by accident or design was connected up wrongly.

Example 9.

A transformer was reported to have failed and as it was at least twenty years old, no particular surprise was felt though, as is well known, transformers are the most reliable part of an electrical system. As it was situated in the pit bottom it was brought out of pit, and an examination shewed that small globules of melted copper were to be seen on various parts of the winding. Tests of insulation and resistance shewed no defect but as it was thought that possibly the fault had blown itself clear, it was decided to dismantle the transformer windings. As this proceeded no evidence of a fault could be discerned, doubt was expressed, as to whether a fault really existed and a thorough enquiry and investigation in other directions was obviously necessary. It was eventually discovered that the fault had occurred where the armoured cable entered the trifurcating box, and as this had not been filled with compound the fault had blown the bits of copper on to the windings. It would therefore appear desirable to make sure in cases of this kind that it is the transformer itself which is at fault ; this example shews the folly of jumping to conclusions.

Discussion.

Mr. STAFFORD, Chairman, in opening the discussion said that when he read that Mr. Williams was to read a paper he looked forward to something good and he had not been disappointed. We all ought to turn each failure into a success and not let it stay as a failure, as only by so doing could recurrences be prevented.

Mr. BLEACH said he would like to assure Mr. Williams that the collieries around Doncaster did have breakdowns as well as the older collieries but, perhaps due to the fact that they are generally speaking drier pits, breakdowns were not so frequent.

In his experience one of the greatest sources of trouble had been the design of cable connections, i.e., in cable boxes. It seemed to him that in the past manufacturing firms either had not employed the right type of man as designer, or the design of the work had been badly organised. He thought, however, that they now had men with practical experience who kept more in touch with collieries and works. He was sure that the men in charge at the collieries must often have useful suggestions to make regarding the design, and if they were at all shy in writing direct to the firms concerned he urged them to mention it to their chiefs, who would be very pleased to pass the information on to the firms, or at least to bring them forward at these meetings, when they could be assured if the meeting approved them the Branch Secretary would be pleased to pass them forward to the proper quarter. Regarding spare parts for machinery he said he was very pleased to find that quite a lot of firms were issuing lists of spares which they had on hand and could supply from stock ; and they were also supplying lists from which spare parts of switches, starters, etc., could readily be ordered. He pointed out one instance, carbon brushes for rotating machinery, and said that if samples of the brushes which were used at the Colliery were submitted to a reliable brush making firm they would be pleased to make a tabulated list of them with reference numbers for each sample, which would then facilitate the ordering of brushes in the future. He would join with Mr. Williams in stressing the point of systematic examination of plant, which, in his opinion, was essential for smooth working.

In conclusion Mr. Bleach considered that the figures exhibited by Mr. Williams had been well thought out and that Mr. Williams could be complimented on the small percentage of breakdowns, especially when it was considered that all minor breakdowns had been included.

Mr. MANN said he heartily endorsed Mr. Bleach's remarks in regard to cable boxes. Referring to Mr. William's remarks regarding trailing cables he said that in his opinion the more recent method of putting an earth shield (ferflex armour) on the separate cores appeared to him to be a much better arrangement than that of ferflex armouring overall, and gave much better protection.

Mr. HIGGENS complimented the Doncaster Sub-Branch on the splendid papers which they had received during the current session. Referring to the remarks by Mr. Williams on assembly and dismantling of apparatus in the pit, and his inclination to lay blame upon the designers, it was important not to overlook the question of price. There was no doubt that if two firms tendered prices for a similar class of machinery almost without exception the one quoting the lower price got the order irrespective of which piece of apparatus would be more suitable for the job.

Mr. Williams had touched on the question of standardisation of apparatus, and Mr. Higgens said he felt that there was room for this in connection with the machinery. He thought the time was ripe for the manufacturing firms to get together to see if they could not do something in this direction.

Mr. Williams had mentioned the matter of engineers using machinery not being backward in coming forward regarding complaints ; he, Mr. Higgens, would say that as a representative of a manufacturing firm, the makers appreciated any comments that were made as it was only by criticism and suggestions of that kind that they got useful ideas of the performance of machinery under working conditions ; and, naturally, if they did not receive any complaints they were of the opinion that the article put forward was giving satisfaction.

Mr. Higgens went on to say that in regard to the question of water getting into machinery, he was of the opinion that the use of grease, as suggested by Mr. Williams, was rather a dangerous practice ; the grease was liable to make a total enclosure and in the event of an internal explosion there was a possibility of the apparatus being blown to pieces.

He was interested in the figures which Mr. Williams had submitted, but it appeared to him that there was a posibility of a discrepancy in the " Breakdowns due to Design or Material ", as in colliery A the percentage was 49 and in B 33. Presumably the two collieries had the same plant and by the same makers. Again, the " Human Element " figures shewed a big discrepancy, A shews 10% and B 25% ; surely the same type of man was employed at both collieries. Mr. Higgins could not understand therefore, why there should be such big differences.

Mr. WATSON SMITH said that some of the avoidable breakdowns came under two classes—

(a) Through the designers and manufacturers of plant not being fully conversant with the usage of same ; and it was a necessity that the user should, by hints and pressure, get the designer and manufacturer to build plant, which would as far as possible, be immune from avoidable breakdowns during usage.

(b) By inefficient supervision ; in this direction he emphasised that where there was a lot of electrical plant underground it should be recognised by the electrical engineer and his staff, that it was equally their duty to go down the pit to examine and inspect, as it was their duty to tour the surface and inspect ; just as the colliery manager went down the pit to inspect and examine, so should the electrical engineer.

Mr. WILLIAMS said he was very pleased to hear Mr. Bleach's remarks and it was interesting to know that they did have breakdowns even at modern collieries. He agreed with Mr. Bleach regarding design and especially with regard to terminal boxes. With reference to Mr. Higgen's remarks, he was interested to gather that manufacturing firms would occasionally admit they were sometimes to blame. Regarding the use of grease he did not anticipate any trouble in the way suggested by Mr. Higgins. As to Mr. Higgin's comments on the apparent discrepancies in the figures, the figure of 50% of breakdowns was due to a considerable amount of trouble they had experienced on one particular type of air-break switchgear. He agreed that the figures in respect of " Human Element " breakdowns were rather disturbing, but when one considered that there were fifteen at one colliery and ten at the other and that all minor breakdowns had been included he was of the opinion that the figures were satisfactory. He could assure Mr. Higgens that these figures as obtained from actual results agreed more or less with those published by insurance companies.

WESTERN SUB-BRANCH.

Report of H.M. Electrical Inspector of Mines, 1929.

Discussion.

(*Meeting held 11th April,* 1931).

Mr. W. M. THOMAS, Chairman, opened the proceedings by mentioning that it had become the practice of the Western Sub-Branch to give each session a meeting for the review and discussion of the Report of Mr. Horsley, H.M. Electrical Inspector of Mines. He was particularly pleased to see Mr. Horsley present at the meeting: members would feel indebted to Mr. Horsley who had travelled all night from the North to meet them and they would also see in that abundant evidence of his interest in the work of the Association and particularly of this Sub-Branch.

Continuing, Mr. Thomas said the Report as usual was informative and concise, written in that lucid style characteristic of Mr. Horsley. They had all much to learn from the latest report though it was difficult to find in it anything of a very controversial nature. In the opening, on page 4, it was noted that the use of electricity in mines was definitely on the increase year by year, and whilst the last annual increment shewed a falling off, that could reasonably be attributed to industrial depression.

Unfortunately, there were 11 fatal accidents involving the loss of 19 lives in the year 1929: 9 being due to one accident, the explosion at Milfraen. A large proportion were attributable to electric shock: trailing cables accounted for 3; plug connectors accounted for 3; switches accounted for 2; an unfit motor accounted for 1; and a misunderstanding accounted for 1.

On pages 9 *et seq.* Mr. Horsley gave a detailed account of the circumstances leading up to each fatal accident and concluded with a statement as to the causes and preventive methods. Among these he mentioned: carelessness; punctures and damage to cables; faulty connections; mistakes; omission to observe routine tests for electrical defects; and ignoring the provisions of general Regulations 131(g).

Whilst machinemen were involved to the extent of 50% of the fatals there was a significant absence of electricians in the list (p. 7 Table 4); surely a fact that could be taken as a credit to the work of the Association.

Under causes and preventive methods there seemed to be need of:—

(a) Better supervision of coalcutting machines.

(b) Better attention to the provisions of Regulation 131 (g).

(c) Proper enclosure of coalcutting machines (Milfraen Explosion).

(d) Care in the laying of trailing cables.

Under ignition of firedamp, during 10 years (1920-1929), 22 in 710, i.e. 3.1% were attributable to electricity with 9.8% fatalities; a very small proportion of the whole.

Of the 54 notifiable non-fatal accidents, it was interesting to see how the percentages compare under contributary causes (Table 7).

	1928	1929
Misuse or negligence	44%	59%
Defect or Design, etc.	17%	17%
Faults of maintenance	28%	15%
Unforseeable	11%	9%

These comparisons reflected credit on the electrical staffs at collieries for improved maintenance and for care in that direction.

Switchgear and trailing cables each account for 24 of the 54 accidents (Table 8), i.e. 88%. This led Mr. Thomas to think that machines generally were safe and that it was to external gear and trailing cables that particular attention should be given for a reduction in accidents.

Mr. J. A. BERNARD HORSLEY first directed attention to progress as shewn by statistics in Table 1 and Appendix A. The last column of Table 1 is for a period of 6 months owing to an alteration in date for which returns are made. It was surprising, he said, in view of depression in the industry, that the rate of increase in 1929 had increased almost to the rate recorded in 1925. Referring to Appendix A, where the use to which electricity is put is analysed under many headings, the most important increases have been in pumping and haulage underground, then for washing and screening, then winding and miscellaneous services above ground. The relative increase in the use of electricity for coalcutting and conveying is substantial. The South Wales division does not contribute largely to the machine mining of coal, but it is growing.

As to accidents, Mr. Horsley said that while it was encouraging to observe from Table 6 that, notwithstanding the increase in motors installed, the accidents from shock were more or less stationary, there was a good deal in the incidence of particular accidents that is not so satisfactory. The repetition of avoidable accidents is clearly shewn by analysis in Table 7 on page 22. For the 5 years analysed therein, 55 of the accidents or 22% of non-fatals were due to faults of maintenance, and 115 or 46% due to misuse of plant or negligence. In placing an accident in category (d) he considered whether, in the present state of the art, the accident could reasonably be regarded as unforseeable. By defects of design he did not necessarily mean that the design was in itself bad, but that it was perhaps unsuitable for the purpose, e.g. an industrial type switch used where a mining type switch was really required.

Referring to Table 9 on page 27, he pointed out how many accidents, fatal and non-fatal, were associated with the use of trailing cables and plugs. The percentage of the totals shewn in Tables 3 and 8 being as follows: 1925, 29½%; 1926, 23.1%; 1927, 32.8%; 1928, 45%; 1929, 46.1%. The average for the period is 36%.

The disquieting feature is the apparent increase as time goes on in accidents from the use of trailing cables and plugs. It is inevitable perhaps that accidents should increase with the greater use of electricity in these services. The opportunities for accident are vastly greater at the coal face. Neglect to maintain the earthing circuit properly is at the bottom of many of them. One recognises the difficulty in applying the tests necessary. It involves a certain amount of dismantling, and cutting off the supply. He had suggested in a recent address to the N. of E. Branch (Vol. XI. No. 128, p. 396) the provision of a permanent testing circuit to avoid interrupting the service, and this suggestion had attracted sufficient attention to lead to one colliery engineer making enquiries of the cable makers for quotations for a suitable cable. Mr. Horsley sketched his proposed testing system on the blackboard (see Fig. 4, p. 396, *Mining Electrical Engineer*, May 1931). He said that earthing alone is no guarantee that shock will not be received. It is absolutely necessary for safety that some automatic device should be used to interrupt the faulty circuit. Unless the neutral point is earthed, there cannot be any guarantee that the fuse will operate when a fault develops. Even where the neutral point is earthed and where there is overload protection, it may be that there is sufficient resistance to prevent the automatic device from functioning. It is advisable, therefore, to use leakage protection. This can be made much more sensitive than over-current protection. On the occurrence of a fault, the faulty circuit should be isolated as quickly as possible. Statistics shew that fatal shocks are not infrequently obtained from systems which are normally insulated. There is usually enough distributed leakage current to provide a return path. The electrostatic capacity of the cables will be sufficient, on a high voltage system, to hold the neutral point at earth potential, so that a person touching one live pole will receive a serious, or perhaps a fatal, shock, although there may may be no fault on the system itself.

Mr. Horsley also sketched an illustration of his remarks on the offset potential drop. (see Figs. 2 and 3 p. 395, *The Mining Electrical Engineer*, May 1931).

Mr. RICHARDS.—One thing very noticeable in the commencement of the Report was that the rate of increase in the use of electrical power for general development in mines has been maintained. For a period of six months, there was an increase of 11,000 h.p. above ground and 20,000 h.p. below ground.

Again, it would be noticed from Table 2, that the percentage of a.c. plant compared with that of d.c. plant, shewed a decrease of 4.2%, in this particular division, and there was a slight decrease in that of the Cardiff Division. It might be taken that that was more or less due to the economic position in the South Wales Coalfield rather than to a steady increase in the amount of d.c. plant installed.

It was regrettable that the loss of life due to accidents had been what was reported, especially so as in one case nine lives were lost and five other persons injured, due to open sparking on a coalcutting machine. It made one realise that the maintenance of plant of this nature at the coal face must be of a very keen and thorough nature indeed. The analyses given shewed clearly the different classes of labour, the nature of the equipment, and the various types of accidents. These should enable one to get down to brass tacks as it were, for the avoidance of similar accidents.

The table on page 9 giving details of ignition of firedamp during 1920-1929, was most interesting, especially so considering the extensive use of electricity underground these days and its consequent maintenance.

In his general comment on the Fatal Accidents, Mr. Horsley mentioned two important points:—

(1) The need of better supervision on coalcutting machines.

(2) Compliance with the requirements of Gen. Reg. (1319).

From the detailed reports of the respective accidents, one must agree that there had been a lack of supervision in those instances, and that for safe working the necessary staff for proper maintenance must be provided, and that the Guide given in the Explanatory Memorandum re periodic testing should be strictly adhered to.

The records of accidents were well worth the study and if every electrician after studying them would apply the probabilities of such accidents occurring on his own system and analyse the system with a view to the prevention of such probabilities, then this report would be fully serving its purpose.

Referring to detachable cable end boxes, the speaker thought they were very useful and he had found no difficulty in getting collieries to have them installed. As Mr. Horsley had stated, they tended to greater reliability and convenience.

In the report emphasis was laid on compliance with the General Regulation 131g. With modern draw-out switchgear no serious difficulty could arise and, as Mr. Horsley stated, manufacturers have and are giving the matter every attention. With the ordinary draw-out type of switch, a permanent attachment could be obtained. The speaker had gone into this matter and found that the approximate cost of installing this feature in D.O. switchgear was about £20 per switch. With the older type of switchgear, certain difficulties arose and some switchgear would either have to be withdrawn or its construction altered. Mr. Horsley's Appendix 'E' was a very timely one and cleared away doubts which otherwise might have led to serious consequencies. It was well worth serious study and should serve as a useful guide when installing apparatus to comply with this regulation.

In his remarks on accidents involving electricians, or assistant electricians, Mr. Horsley mentioned that it was not necessarily the person ignorant of the danger who ran the greatest risk: indicating that electrical staffs should take the utmost care. No doubt, there were many cases where in order to keep things going electricians had taken unnecessary risks and perhaps in some cases they had been forced to do so.

Mr. S. T. FOKES said there was only one point which presented difficulties in his particular case. It was that regarding the accident No. 10 in the report. It mentioned Circular 23, which they all received, but the application of which they found most difficult. In Mr. Fokes' case there were something like 9 or 10 different makes of switches, apart from different types of the same makers, and in order to earth and short any line before it was worked on, a different arrangement must be made for each. Makers did not seem to be catering for Mr. Horsley's suggestion, as no one was able to offer a reasonable fitting for the purpose. He would therefore be very glad to know what views Mr. Horsley had on the matter.

Mr. COPE thanked Mr. Horsley for coming down to address the members on his report, and said he had read the report as a man in charge of colliery plant. He had always had misgivings as to what might happen, especially as Mr. Horsley comments on the fact that seven fatal accidents due to shock occurred with coalcutting machinery, but Mr. Horsley does realise that this is the worst place in a colliery for electrical plant to work. The most valuable part of the report was Mr. Horsley's indication as to how to handle a supply of electricity to a coal face that was moving forward or backward. It was very difficult to arrive at a right conclusion, and he thought that what Mr. Horsley had recommended was the correct procedure to adopt.

Mr. Cope started to use coalcutters about 5 years ago, and gave his experience in this connection. In regard to the cable, he said the abuse of this was instructive to him as to what cable could stand, and he found out for the first time, the limits to which a cable could be put. S.W. armoured cable was of no use at all. They put in a cable of H.T. 3000 v. paper insulated, bitumen sheath, D.W.A. cable, that served its purpose admirably, and he had cable in use for four years with constant handling.

Another problem he had was the weight of the cable compared with the gate-end switch, the latter of which was too light. Mr. Horsley made another suggestion in one of his reports about a semi-flexible cable joint to the gate-end switch, and that method was cutting out a good deal of the risk.

Another source of trouble was the kind of material used for insulating the live terminals of plugs and sockets. The material carbonised and there was a sort of smouldering. He would like someone to bring forward a porcelain insulator to stand the rough treatment it would have and which would at the same time prevent the creepage of the current.

Mr. Cope then referred to the accident reported on page 25. It was an exceptional accident, but he asked what steps Mr. Horsley would suggest being taken to deal with a point like that. Re trailing cables, he said Mr. Horsley, when at his colliery some time ago, indicated certain experiments he was making with regard to these. He thought a certain limit of length of cable should be made compulsory.

Mr. HEZEKIAH THOMAS said it was a great pleasure to have Mr. Horsley with them, they should appreciate his work, and what he was doing in the prevention of loss of life due to accidents in mines. When they considered the amount of electricity in use, the percentage of accidents was very low. Mr. Horsley was a great help to colliery electricians in suggesting remedies for faults.

Mr. PHILLIPS referred to a case where a coalcutter man was getting slight shocks on the coalcutter. On testing the circuit he found that the blow-out coil was dead earthed. Having regard to the fact that the coalcutter was a mile inby, did that indicate too great a resistance?

Mr. RUTTER said their attention had been drawn to the increased efficiency of the electrician, and he believed that was greatly due to the benefits derived by attendance at meetings of the Association. There was no doubt that the electrician having no coalcutter installations could not appreciate the difficulties of the electrician who had those machines to contend with. For the maintenance of trailing cables, for instance, constant attendance and supervision was required. They had still a long way to go as regards portable apparatus. He asked Mr. Horsley whether the ordinary conductive bond tester was likely to lead one astray: he also submitted another question concerning the leakage protection for a 3000 v. three-phase, with insulated neutral.

Mr. HORSLEY, in reply, referring to the use of direct current in South Wales, said that the slight increase in comparison with the figures for 1928 was accidental or casual, because d.c. was slowly declining. It held the field in the early days because it was the first to be introduced:

satisfactory induction motors had not been developed, or, if they had been, colliery people were not satisfied as to their capabilities. There were collieries which begun with d.c. where they could not face the prospect of scrapping all their existing d.c. plant, but where amalgamations were taking place, there was a tendency to convert the installations to a.c.

As to the organisation of lectures on the lines of those indicated on page 27 of the Report, he thought that was a good suggestion. Such lectures were held in other areas with great success.

Regarding the comments read by Mr. Richard, one referred to the difficulty of complying with the regu- ations, and suggested that the manufacturers were not prepared to meet the requirements of G.R. 131(g). Mr. Horsley could contradict that, as manufacturers were quite prepared to meet these requirements, but, of course, at a price. It was obviously not possible to convert existing switchgear without expenditure. It may sometimes be preferable, or less expensive, to purchase one switch solely for the purpose of earthing the circuit, one which could be plugged into the circuit upon which it was desired to work. That was a simple and satisfactory solution entailing no change in the existing equipment.

He said it was impossible to formulate a general solution. It was far better to call in the manufacturer and discuss with him the best way of making the necessary provisions. He had drawings in his office shewing what the manufacturers were prepared to do.

As to the use of unscreened trailing cables, in Northumberland he was told one colliery had 20,000 yards of trailing cable in use, and they had not had a fatal accident for 10 years. Not a yard of this was of the unscreened type, but they always associate leakage protection with the coalcutter circuits. He hesitated to recommend screened cables in all cases because they required special care in handling and maintenance and presented special difficulties in repair. It was fatal to such a cable to coil it down like a rope. It was essential that such cables should be flaked in a figure of eight. In maintenance, it was vital that every cut and puncture in the sheath should be promptly attended to. It had been said that the ferflex screen quickly perished, and it would do so if water were allowed access to it. Copper conductors insulated with rubber were always tinned; the tinning was applied, not to protect the copper from the rubber, but to protect the rubber from the copper.

As to the use of an auxiliary earthing bond for couplings, his experience led him to think that it was hopeless to expect the coalcutter man to attach that bond properly. He believed a reliable connection could be made with a plug in which the earthing connection was first made, and then completed by the retaining screw. At many collieries earth continuity protection was adopted.

Referring to Mr. Cope's remarks on cables, he would not select a paper cable either with lead or bitumen sheath. If the cable had to be frequently moved, he would prefer either a bitumen or rubber compound insulation. Paper insulation was excellent for permanent cables. Referring to the accident in which three pit ponies were involved, there was no reason why a local earth plate should not be used where the supply was trasformed down, but the difficulty was to secure a satisfactory connection with the general body of earth.

Referring to the case of the coalcutter man who escaped with slight shocks when the insulation in the controlling switch broke down, he could only suggest that the place was dry, that the earthing conductor was in good order, and that the general insulation of the system was good. If the return path be of high resistance, that high resistance would be in series with the man's body and would reduce the intensity of the shock he received. The only safeguard was to make sure that the earth conductor had a sufficiently low resistance.

It was possible to apply leakage protection to d.c. systems.

Mr. Richard had suggested that the earth continuity testers may lead to a false sense of security. Mr. Horsley gave a sketch on the blackboard of a suggestion he had made in this connection for checking the testing instrument (see Fig 1, p. 395, *M.E.E.*, May 1931). As to leakage protection for a high voltage system with insulated neutral he could suggest none that was completely effective. The remedy was to earth the neutral point. There was everything to be said in favour of this, and nothing to be said against it.

Mr. REES (Swansea Corporation), said he was glad of the privilege of tendering their thanks and appreciation to Mr. Horsley for coming down to address them. It was a distinction to the Branch to have one of Mr. Horsley's standing among them, to help them. It was essential for electrical engineers to realise how important it was to maintain a high standard and to keep up with the times, making use of all the improvements that were brought forward. They appreciated the visits of Mr. Horsley very much, and he proposed, with great pleasure, a hearty vote of thanks to him.

Mr. YATES seconded the vote of thanks with equal pleasure, and said they regarded Mr. Horsley as their most valuable co-operator in the work of promoting higher efficiency and greater safety in the use of electricity in the mining industry. He had rendered great services to the Association, and their thanks were due to him for his work.

CUMBERLAND SUB-BRANCH.

Firedamp Alarms and Gas Operated Switchgear and Lamps.

H. T. RINGROSE, B.Sc. (Lond).

(*Paper read* 23*rd March*, 1931).

The members will all be fully acquainted with the present system of gas detection in mines by which the estimation of the percentage of gas present, is judged from the cap formed on the top of the reduced flame of an ordinary miners' oil lamp: the method that is now universally adopted in all mining countries for the estimation of gas. The author makes no complaint against this method, but can agree that the use of the oil lamp for the detection of gas by officials is the best and most reliable means yet devised.

With the advent of the electric lamp, of which over half a million are now in use in Great Britain, the men are provided with a better means of illumination, but at the same time they are deprived of the safeguard which an oil lamp undoubtedly is, namely, that it will detect gas whereas the electric lamp will not. An obvious comment is that frequent tests for gas are made by the officials. The reply to which may be, that if the Mines Acts be carried out to the letter, there is no obligation on their part to test for gas more than once in any one locality over a period of five hours. In the course of five hours, even in the course of five minutes, explosive gas may arise, and if the miner, with the electric lamp is to rely only on the periodic visits of the deputy, then he may be in a very dangerous situation for hours without ever knowing of it.

To overcome the disadvantage attached to the ordinary miners' electric lamp, the author has suggested a certain means of giving the miner automatically a signal of the presence of gas, long before it reaches the explosive stage. The author suggested, in other words, a means of gas detection which is entirely independent of the human element. His means of testing is devised so as to test all the time, from second to second, and immediately the gas reaches above a predetermined percentage, a visible or audible signal is given.

(The author by practical experiments demonstrated the principles of gaseous diffusion through porous vessels).

The pores of the pot are very small, in fact they are of molecular dimensions, so that it is quite impossible by any means whatsoever to block them up by particles of the finest dust; such particles in size would bear the ratio to the size of the pores, as the size of the earth is to the size of a cricket ball. Cigarette smoke or even bacteria are unable to pass through, yet all gases pass through the walls of the pot very easily. To illustrate this fact, attach a larger porous pot, made of unglazed earthenware, to a liquid monometer. Bringing gas similar to marsh gas, near the porous pot, sets up a pressure in the porous pot, as was clearly shewn on the monometer. This experiment was the one usually made at Technical Institutes, to measure the different rates of diffusion of gases through porous media. In this particular case, the gas being lighter than air, passes by diffusion through the porous pot quicker that the air inside can diffuse out, there is therefore a pressure set up. Instruments working on this principle have been suggested for use in the mines but in practice they are quite useless, as such an arrangement only works intermittently. In order to take a test for gas, it is essential that the porous pot should be filled with pure air each time and, under the best conditions, only one test can be taken. Some three years ago, whilst carrying out some research the author found that it was quite possible to use a porous pot to shew gas, without the necessity of continuously replenishing the interior of it with fresh air. Use was made of the fact that marsh gas, CH_4, when burned with a sufficient supply of Oxygen, produces Carbon Dioxide, CO_2, and Water, H_2O, according to the chemical equation below

$$CH_4 + 2O_2 = CO_2 + 2H_2O.$$
$$2 \text{ vols.} + 4 \text{ vols.} = 2 \text{ vols.} + 4 \text{ vols.}$$

Out of every 6 volumes of Marsh Gas and Oxygen burning only 2 volumes of Carbon Dioxide remain, the water, of course, condensing at the temperature. When marsh gas is burning on say a hot wire inside the chamber, there is a loss of pressure (or vacuum) produced in the chamber. (An experimental apparatus illustrating this was shewn. It comprised a small platinum filament, arranged in a fuse form, which could be made incandescent by the battery. Over it was placed a small enclosed earthenware porous pot, and except for its porosity, was perfectly air tight. There was also a connection from a monometer to the interior of the porous pot, so that any change of pressure inside the porous pot could be shewn).

If any inflammable gas whatsoever be near the pot, diffusion of the molecules of the inflammable gas causes it to pass from the outside to the interior of the pot. If the temperature of the wire is sufficiently hot, combustion of the inflammable gas occurs, and during the process there is a tendency to produce a vacuum. The vacuum, however, cannot increase indefinitely, as owing to the pot being porous, there is also the tendency of the vacuum to destroy itself, and thus a differential vacuum is produced in the porous pot. This latter will of course in its turn depend on the number of molecules surrounding the porous pot.

This is the important fact: the vacuum produced by the burning of any inflammable gas on a hot wire inside a mounted porous chamber, gives a reading directly, proportional to the percentage of gas in its vicinity. When this fact is fully grasped there will be no difficulty in completely understanding the various applications of this system of inflammable gas analysis.

For instance, the vacuum produced by the burning of the gas inside the porous chamber on the hot wire can be made the operating force to unite two electrical contacts together. When the gas round the porous chamber reaches above a certain pre-determined amount, the electrical circuit will be completed, the red light put on or a bell rung, or further, the vacuum produced can of course easily be made to break an electric circuit or short circuit, say a no-volt coil of a circuit breaker. It can in fact be made by suitable relays to bring into operation any class of electrical machinery of any magnitude.

(The author then exhibited and described one of the latest instruments using this principle for gas detection as applied to a firedamp alarm).

The alarm consists of a miners' lamp battery, on to which is fixed a chamber containing a porous pot and a hot filament together with a double gauze protection. At the top of the porous chamber is mounted a miners' illuminating lamp, together with an alarm signal; it is coupled in series with the contacts of the bellows diaphragm.

Whenever the apparatus is in an atmosphere of inflammable gas, diffusion introduces the gas into the instrument. The gas passes through a filter, then through the porous vessel to the hot filament, and the vacuum produced is made to draw in the bellows diaphragm which cause two platinum points to come into contact. The circuit is thus made through the red lamp, and an alarm given of the presence of gas. As long as the percentage of gas remains, there is a vacuum in the porous vessel, and therefore the alarm lamp remains on. Immedaitely however, the percentage of gas falls, the vacuum diminshes, and in time the electric contact is broken, thereby extinguishing the alarm. Thus it is that this alarm can never be in action without operating the two electric contacts, the distance between which determines the percentage at which the lamp is set to operate, and according to the Mines Department instructions, all lamps are now set to operate at the 2½% figure. These lamps have been carefully tested by the Mines Department with satisfactory results, including the mechanical test, which consisted in dropping the lamp a distance of six feet a number of times on to a wooden plank. These tests did not affect the accuracy of the lamp.

Experience has shewn, however, that when these lamps are used in quantities in the mines, it may occasionally happen that they receive a blow of such a character that might affect the setting. To guard against the possibility of extremely rough usage upsetting the lamp, a piece of apparatus is now provided for the lampman's use, whereby the lamp can be tested if necessary every shift. It has been shewn that the vacuum inside the porous chamber is proportionate to

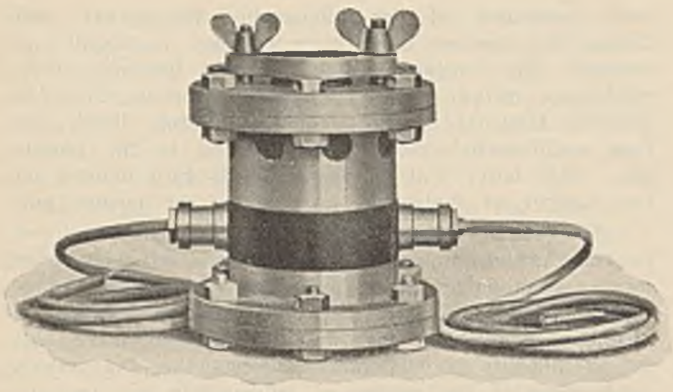


Fig. 1.—The "Gas Sentinel."

the percentage of gas round the lamp. A 1 inch vacuum water pressure gauge, corresponds to 2½% of gas, and thus it is that a lamp set at 2½% of gas, has its contacts made if 1 inch of vacuum be applied to the lamp artificially.

This piece of apparatus enables the lamp man to apply the known vacuum to each lamp before it is taken into the mine. If it be found that a higher vacuum than 1 inch is required, then it means that the contacts be too far apart, and the lamp man must make adjustments by the means provided. On the other hand, if the contacts are too close together, then the alarm will operate below 1 inch vacuum, and the lamp man can conversely, separate the contacts by loosening the screw. These simple tests ensure that no lamp can be out of order prior to its going down the mine.

There is another very simple test, which can be applied to the lamp. After leaving the lamp on for a few moments, say 40 seconds, if the latter be switched off and then momentarily switched on, the signal lamp winks. This is clear evidence that the lamp is in working condition, and particularly that all the electrical connections are sound, and also that the alarm bulb is not broken.

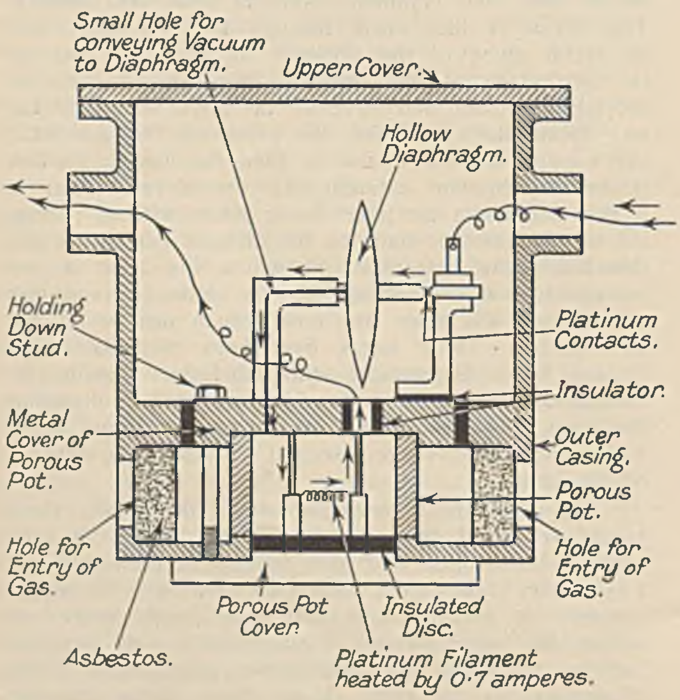


Fig. 2.—Diagram of the Interior of the "Gas Sentinel."

When the lamp is in use underground the miner can see at a glance the luminosity of the filament, which is a proof that the alarm is in order and will give warning if gas should appear at or above the setting of the lamp.

The filaments are supplied in lots of 12 and, by a Government order, it is necessary to change them each shift. As the action of the lamp depends entirely on combustion, any other gas, such as CO_2, in the atmosphere of a mine has no effect on the action of the alarm, the lamp being entirely selective to gas of an inflammable character.

Many industries in which inflammable gases or vapours occur, have found the lamp of great service in giving warning of danger. The Admiralty use this principle for the detection of Hydrogen on submarines, and Corporations are now using it extensively for street man-hole work. Another interesting application is the use of this system of inflammable gas detection for giving an alarm when explosive gas arises in coal bunkers, particularly in those containing pulverised fuel.

(The author then dealt with the system of automatic gas analysis, as adopted in gas operated electrical gear, and in conjunction with experimental demonstrations, gave the following description).

The apparatus, termed a "gas sentinel," is so constructed that in the presence of gas an electric contact is either made or broken. In the latter case it is termed a "series sentinel," and is illustrated in Figs. 1 and 2. The action and construction of the sentinel may be followed in the diagram (Fig. 2). Enclosed in the apparatus is a porous pot, within which is a special filament heated electrically. Any gas present in the atmosphere percolates via gauze-covered holes through the porous pot, and is slowly burned by the heated wire. This creates a partial vacuum in the pot, and the vacuum so produced passes to the interior of a diaphragm and separates two platinum contacts, thus breaking the electric circuit. This breakage of current can be used for a variety of purposes. If the sentinel is in series with lamps, not only are they extinguished, but the distant circuit breaker is operated to make the cable dead. Thus the whole of the lighting, etc., becomes safe in the presence of, say 1¼% of gas.

A typical illustration of the application of the gas control system to an electric starter is shewn in Figs. 3 and 4. Here is depicted the first gas-controlled starter ever put in the mines. Its action will be grasped from the following description (Fig. 4). A 500 volt d.c. current passes in the direction of the arrows through the overload coil OL to the contact B, and thence to B_1, normally in contact with B, and energises the coil S, thus maintaining B_1 in contact with B and at the same time releasing the catch A_1 and freeing the starter handle H. The current then passes through the no-volt coil and the filament F_1 of the sentinel. Finally, it passes through five 100 volt 150 watt lamps placed in series and some distance from the starter. The total candle-power of the lamps is 1500, and they are spaced at intervals of 25 yd. in the haulage road.

It should be particularly noticed the circuit is a series one. To use the starter in the first instance, it is necessary for the official in charge to remove the padlock at pust button B_2. The latter is then pressed to lift up the armature so as to touch stud B and at the same time to release the starter arm H. All the coils thus become energised with the series current, the lamps and filament F_1 in the porous pot being incandescent. Moreover, the motor can then be started in the usual way.

Consider what happens should, say, 1½% of gas appear in the atmosphere near the sentinel placed in this case at the top of the starter. Gas burning on the incandescent filament F_1 causes, in a few seconds, the platinum contacts at C to touch. This immediately short circuits the no-volt coil and the coil S. The starter handle is tripped and the armature falls, causing the contacts B, B_1 to be broken, thus extinguishing the lights. Moreover, the catch arm A_1 locks the appliance and none but an authorised person with the necessary key can operate it again. Thus the apparatus is selective to gas. If it is desired to stop the motor, a push button is arranged to short circuit the no-volt coil, but this operation has no effect on the lighting nor is the starter arm locked.

As the circuit is a series one, it will be observed that if one of the lamps is broken, or a cable severed, then the starter immediately trips and locks. Moreover, if a short circuit develops, the filament F_1 fuses, breaks circuit and trips the starter.

To protect the lamps, which might be placed some distance away, a series sentinel, previously described, can be placed near them. If 1½% of gas appears, the circuit is then broken by the sentinel and the distant starter is operated.

The description above is that of a system applied to a starter, but it is obvious it can just as easily be fitted to a circuit breaker or any other piece of electrical apparatus. It should be noticed the action is netirely independent of the human element—the gas, long before it exists in dangerous quantities, cutting off the main supply of current.

The invention is suitable for ensuring greater safety from inflammable gas in the case of lighting systems

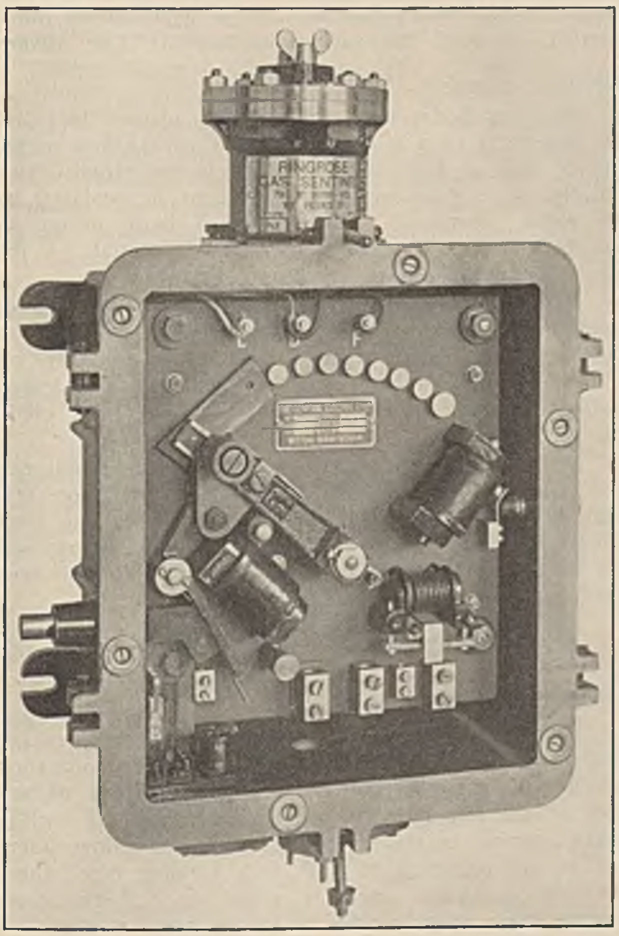


Fig. 3.—Starter fitted with a Gas Detector.

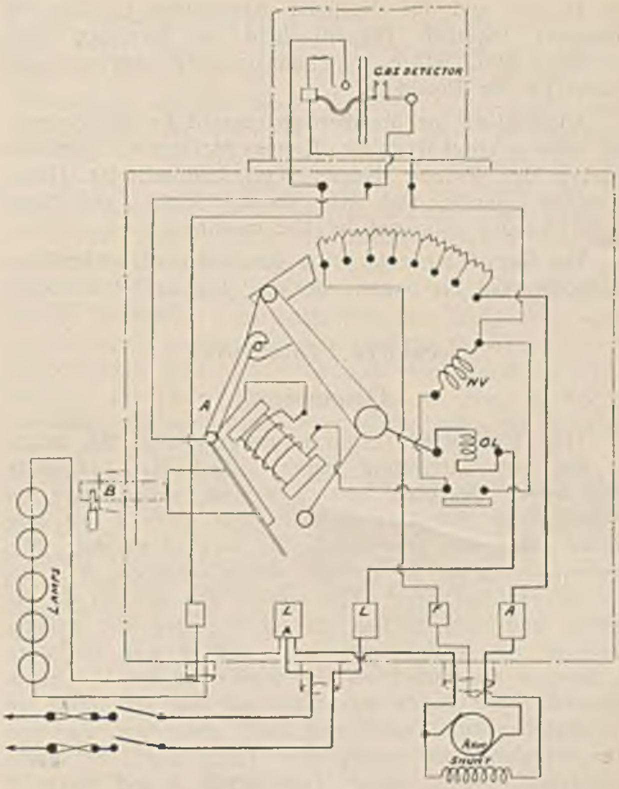


Fig. 4.—Starter fitted with a Gas Detector. Catch A can only be lifted by use of padlocked push B.

of mines, one Ringrose detector being connected in circuit with a plurality of lamps spaced at intervals, so that the whole of the lamps in any part of the mine in which gas appears would be extinguished on the appearance of inflammable gas. By the use of this method of lighting, the coal face and roadways of mines could be lighted to any degree desired, and with safety. Most of the accidents in mines are caused by falls of roof, men being trapped by the machinery in the roadways owing to a great extent to the defective lighting. Adequate lighting of mines would also, if not eliminate, greatly reduce nystagmus from among miners, a disease from which a large number of miners are constantly off work at considerable cost to the industry.

At the present time, the introduction into mines liable to the presence of firedamp, of mechanical coal-cutters, conveyors and secondary haulage actuated by electrical energy is prevented owing to the danger of ignition, a danger which would be greatly lessened, if not prevented, by means of the Ringrose safety device, which could be applied to cutting off current on the advent of inflammable gas. The great economic advantages which would be secured by the better lighting of mines at or near to the coal face, and in the runways in which the haulage machinery is placed and by the more extensive application of labour-saving devices, are obvious.

WEST OF SCOTLAND BRANCH.

A meeting of the West of Scotland Branch was held at the Royal Technical College, Glasgow, on 25th March last. Mr. R. D. Rogerson, Branch President, occupied the Chair and there was a good attendance of members. At the outset the Hon. Secretary (Mr. W. G. Gibb), read the Minutes of a Joint Meeting of the Branch and the National Association of Colliery Managers (Scottish Branch) held on Saturday, 20th February 1931, which were unanimously approved and signed by the President.

Applications for Membership, passed by the Council, had been received from Mr. Thomas McDonald Chambers, Shotts; Mr. William Rennie, West Lothian; Mr. Gavin Whitelaw, Shotts, and Mr. Thomas Lister, and these were formally approved by the meeting.

The formal business being concluded, Mr. Alexander Lighbody read his paper, entitled "Leakage Protection."

Leakage Protection.*

Discussion.

THE PRESIDENT, having congratulated the author on his very interesting paper, asked Mr. Lightbody what effect the core balance system would have on a three-phase, four-core flexible cable when a live core on the cable was penetrated. By way of example, Mr. Rogerson recalled an accident which occurred at a certain colliery last year. The section was worked on the double unit system, and during the day the driving chain of the loader gave way, and it was necessary to remove the guard on the loader to get the chain repaired. The guard was taken off and put down on the plate at the loader end and, while the workmen were repairing the chain, they found that the guard was lying in their way. They lifted it and threw it to the side of the road. Unfortunately the guard was thrown on to the four-core flexible cable. One of the sharp edges of the guard penetrated the cab-tyre sheath and cut through into a live core. The cable, at the time was lying on the top of dry wood, so that the guard although live was insulated from earth. A few minutes afterwards one of the men that was repairing the chain was standing on the wet plates, and accidentally made contact with the end of the guard, and in consequence, completed a circuit to earth through his body. He was instantaneously killed. Could Mr. Lightbody say whether there was a type of leakage protection on the market that would render such tragedies impossible, or whether he could say if it was essential to instal a flexible armoured cable? The circuit breaker on that particular system was for forty amperes. After the accident happened one or two of the men made an effort to cross some of the empty hutches that were standing between them and the point where the circuit breaker was situated, and every time they touched the wheels of the hutches they got a transmitted shock along the rails from the plates. The working voltage at the face was about 525 volts. Mr. Rogerson said he understood that it only required a few milli-amps. discharge through the human body to cause fatal results, so long as the voltage is high enough to overcome the resistance of the person's body.

Mr. LIGHTBODY.—If there had been core-balance protection fitted on the circuit, whenever the man made contact with the guard penetrating the core the circuit breaker would have tripped, but in this instance a flexible armoured trailing cable would probably have prevented the guard from penetrating the core. Even had the guard penetrated through the armour to the live core, the effect would have been an immediate dead short to earth and consequently the immediate tripping of the circuit breaker, making the whole trailing cable dead and harmless.

* See *The Mining Electrical Engineer*, August, 1930, p 53.

Mr. W. G. GIBB, Branch Secretary, read the following written communications received respectively from Messrs. Robt. Wilson, Arthur Dixon and David Martin.

Mr. ROBT. WILSON (communicated).—With reference to cast iron earth plates: after carrying out a reconstructed installation some years ago, in the Shotts district, on similar lines to the author's method, and before connecting the cables to the pipes (i.e. the pipes standing clear), a potential equal to 0.75 volts was obtained between the two pipes. Did the author ever try this form of test?

Would Mr. Lightbody say what would be the costs of (1) a 100 amp. twin distribution panel, suitable for for 500 volts d.c. system, fitted with leakage protection device: (2) a 100 amp. panel for three-phase system with protection.

The writer agrees with Mr. Lightbody that colliery lighting is not what it should be. An installation of V.I.R. cables or conduit or C.T.S. has a life of about five years only. An installation of armoured cable, proper fittings and adequate distribution will usually last the life of the colliery.

With regard to continuity tests and a 500 volt concentric system, would the author explain his method of proving that the negative conductors, i.e. negative copper and lead and steel armour, are all equal to 150% conductivity in comparison with the positive conductor.

Mr. ARTHUR DIXON (Communicated).—As Mr. Lightbody indicated in the first paragraph of his paper it is often not realised that, with a continuous addition of new members to the Association, it is advisable to have papers on old subjects from time to time: not only from the point of view of bringing the subjects up-to-date, but of giving the newer members access to information which may already be available to older members through the earlier editions of *The Mining Electrical Engineer*.

Mr. Lightbody has said in two places that, "if one conductor of a system becomes earthed, there is no danger until another earths." That is not strictly true, and the word "danger" might perhaps be replaced by the word "damage." The danger is there in an intensified form owing to the raised potential of the other conductors above earth.

Mr. Lightbody rightly emphasised the keeping of conductors in the earthing system visible, as it is so easy to forget about them until one is forcibly reminded of their presence by a fault which is not cleared owing to corrosion and consequent isolation of the earthing arrangements.

Mr. Dixon agreed that a recording leakage indicator was a good thing to have, but if an installation was kept in good order and the recorder goes on from month to month without shewing anything, there was apt to be the tendency to overlook it and it may even have ceased altogether to function.

Mr. Lightbody mentioned having put in single cast-iron pipes 10 yards apart in the ground, but the writer would prefer two or three shorter pipes buried at a greater distance—say 20 yards.

With regard to the different systems of leakage protection, the core balance type with direct operation which will only operate on a leakage current of say 50% of the full load, is not of much use. If such a heavy current as this is to be allowed to flow, there can be no objection to the much simpler type where overload protection alone is relied on. If the core-balance type of protection is to be used, it ought to relay operated.

Mr. Dixon expressed a distinct preference for the simpler types of protective apparatus, especially for colliery work. He had found that the type mentioned by Mr. Lightbody, where a low reading ammeter shunted by a short circuiting switch and either alarm or tripping circuit set to operate at 5 amps. of leakage or less, gave satisfactory results. At the same time, he would be interested to have other experiences, which he thought would be sure to appear in the course of the discussion on this most interesting paper.

Mr. DAVID MARTIN (communicated).—So far as he goes, Mr. Lightbody has compiled a very readable paper, and it would be useful to draw the attention of those particularly interested to previous papers upon this subject. Amongst these may be mentioned the paper by Mr. H. W. Clothier read before the London Branch on 10th February, 1925, also Mr. Clothier on "Switchgear for Mines" in the "Electrician" 12th May, 1911 and again in the same journal in 1908. The 1925 paper is detailed in *The Mining Electrical Engineer* of March, 1925.

There is a remarkable similarity between the Williams-Rowley system referred to by Mr. Lightbody and that of Mr. H. J. Fisher patented in 1908. Again, the same ground is covered in Mr. Walker's paper read before the Yorkshire Branch of the Association and published in *The Mining Electrical Engineer* of November, 1922. Those two issues of *The M.E.E.*, of November 1922 and March, 1925, may be considered as containing the essential features of all practical leakage protective devices as introduced to date.

Mr. LIGHTBODY, replying to Mr. Wilson's letter: The cost of installing a panel with all the necessary apparatus for a d.c. two-wire system would be about £105. The cost for an a.c. system would be considerably less.

With regard to the conductivity of the negative conductor of concentric cables one method of testing would be: Measure the length of the cable and from a C.M.A. table the resistance of the positive conductor can be obtained. Bridge the inside end of the positive conductor to the negative terminal, which includes the negative copper, the lead sheath, and the steel armour, and measure the resistance of the combination. From the reading obtained deduct the resistance of the positive conductor, which leaves the effective resistance of the negative conductor. It is then obvious whether the negative conductor is 150% conductivity of positive conductor or not.

Mr. Lightbody said the only point raised by Mr. Dixon to which he would like to reply was in connection with core balance, and the statement that it would only operate on a leakage current of 50 per cent. of the full load current. It should be plainly understood that the percentages at which a core balance leakage protective device trips, are percentages of the normal current rating of the particular standard core balance transformer used, and not of the normal loading of the circuit.

Mr. A. F. STEVENSON said the author had not been very clear in his description of the Williams-Rowley system. It was necessary to shew that with that system, there were two earth wires and that the circuit was completed through the body of the coalcutter; not merely that the two sockets in the coalcutter plug were connected together; actual connection with the carcase must be established before the energising coil would operate. At one time, said Mr. Stevenson, there were a number of fatal accidents due to this cause, i.e., broken earth wire: he believed that if the mining industry were in a more prosperous state it was quite likely that the Home Office would call on the collieries to put in safety gate-end boxes of this type.

Leakage devices were intended to prevent heavy current arcs. An arc of 50 or 60 amperes, or something like that, is too much. The idea of working entirely on the earth connection would not do except for the whole system, because if there were supplementary earths at various points where the feeders were it was not possible to know whether the current going through any particular earth was due to a fault in advance of or behind the earth. Core balance is practically a necessity for a proper system which would discriminate between faulty feeders and feeders in good working order; but, said Mr. Stevenson, five amperes or so ought to be the maximum out of balance current for actuating a safety device of that kind.

Mr. LIGHTBODY replied that he had a Winhey Detector installed, the makers of which claimed that the leakage of a person putting his hand on a live terminal would trip the circuit breaker. It was rated to trip with a leakage of about 0.2 amp. and, in fact, working on a d.c. system, it actually trips out with less than that figure.

Mr. HOWAT referred to the question of lighting and said that if there was to be core balance, then the lights must all be switched for one time or simultaneous. He considered that the four lamps on the d.c. system was the finest thing for drawing attention to an earth.

Could Mr. Lightbody give particulars of any indicator that would give by a graduated reading a warning of an incipient or pending leakage? He had had one or two leakage indicators, and whilst they rang a bell or threw a pointer to indicate the presence of fault, he had never yet seen an indicator to give warning of the approach of a serious leakage.

Mr. JAMES R. LAIRD said that a.c. installations pretty well lent themselves to protection, and robust and reliable relays could be easily applied. With d.c. distribution, however, it was not so easy to arrange for protection by leakage trip devices such as those indicated by the systems suggested. It was, moreover, a matter requiring very careful discrimination, whether relating to a pit or a works where highly important safety duties are being carried out by the electrical plant, whether it was more in the interests of safety to carry on with a fault on the system, rather than to shut down automatically and by so doing incur the risk of great danger to workmen. As instances, Mr. Laird quoted very important pumps where standage was not available, cranes carrying molten metal and many other duties. While he would insist on the carrying out of of the regulations governing the use of electricity, he believed personally there was more danger in having all cables armoured and all electrical apparatus earthed than there would be if they were entirely insulated. If the cable makers could only provide self-extinguishing insulation, and plenty of it, a great many of the gadgets and expedients, which had become so profuse and complex as to require more maintenance than the actual work-doing plant, could be eliminated. The human element could not possibly be done without. Why should so much effort be made in the endeavour to do the impossible? A conscientious electrician would look after faults when they shewed on the indicator, and would clear those faults when the opportune time arrived. Mr. Laird's experience of running and maintenance was that a week's neglected repairs was not caught up in six months. It was his opinion that the schemes carried out by the Central Electricity Board did not comply with the Regulations relative to the use of electricity. The making of Regulations could be overdone, and rules could be so hair-splitting in their requirements, that the carrying out of work was seriously hampered by academic suggestions which were in many instances not wisdom.

Mr. A. NAPIER also referred to the fact that a leakage protection system set to operate with one or two amperes, did not seem to afford any personal protection; he being given to understand that so small a current as 100 milli-amperes at 30 to 50 volts a.c. was a fatal shock under ordinary conditions. Even 25 milli-amperes was very dangerous if the body was moist the clothing damp. Would it not be possible to obtain leakage devices to operate at much lower, and safe, current intensities?

Mr. LIGHTBODY.—On the core-balance system, in regard to the 2½ amps. leakage which is the rated trip current, Mr. Lightbody had tried the core-balance system fitted with relays to see what it actually would trip at, and it operated at 0.1 amp.

Mr. DINNEN.—Mr. Lightbody had made reference to the Winhey Detector which provided for instantaneous tripping should a person make accidental contact with a live conductor: would Mr. Lightbody say whether he was familiar with the Entwistle-Jones type for which similar claims were put forward. With three-phase medium tension systems the tendency to-day was to earth the neutral point direct. The choice of leakage protection to be installed therefore would rest between neutral point C.T. tripping, and the core-balance type; the latter could be made selective, while the former, like the above-mentioned types, could not; therefore, as Mr. Lightbody had shewn, core-balance leakage protection which provided for the isolation of a particular circuit on which a leakage occurred was the type most in favour to-day.

Mr. A. NAPIER.—Regarding flexible steel armour cables said he had been using them for a number of years on haulages, pumps, and fans and had yet to experience the first fault. With regard to repairs of these cables he believed it would be a very difficult job and the repaired part would not be so flexible as the rest of the cable. The minimum conductivity of the flexible armour to one core was 72%; he had on test got readings shewing 80%.

Mr. STEVENSON.—How is the armour made up?

Mr. NAPIER replied that each strand had seven wires. It was fairly flexible and could be used for working up coalcutter extensions, they had ten lengths installed, each 110 yards long, for each coalcutter, when that was fully extended they installed 110 yards of heavy armoured cable and coiled up the flexible length in the form of figure eight ready for extensions when required by coalcutter.

NORTH OF ENGLAND BRANCH.

Annual Meeting.

The Annual General Meeting of this Branch was held at the Neville Hall, Newcastle-on-Tyne on 2nd May last. The members were privileged to hear an Address by the President of the Association, Mr. J. W. Gibson. Mr. Bates moved, Mr. Tulip seconded and it was unanimously agreed that a hearty vote of thanks be accorded to Mr. Gibson for his attendance and address.

Mr. E. E. SHATFORD, Hon. Treasurer, presented his report and Accounts to 31st March, 1931, which were adopted.

Mr. S. A. SIMON, M.A., Hon. Branch Secretary, presented his report for the year.

The membership of the branch and of the Cumberland Sub-Branch shewed an increase; the total number being 320. Eight Branch meetings were held in Newcastle and seven Sub-Branch meetings in Whitehaven, the attendances throughout were satisfactory and averaged better than those of the previous session. The meeting on the 14th March was attended by members of the Institute of Mining and Mechanical Engineers and of the Colliery Managers' Association and reached a record attendance of 172.

A visit was paid to the works of the Sunderland Forge and Engineering Co., Ltd., on 10th May and subsequently the members were most hospitably entertained to luncheon.

Visits were also paid to the Ford Paper Works near Sunderland and to the New Central Automatic Telephone Exchange in Newcastle.

A Golf Handicap Competition was arranged at the end of last summer and those who took part enthusiastically advocated a repetition of the event early this season. Very successful Social Evenings were held on 5th April 1930 and 14th March 1931.

The thanks of the Branch are due to the Papers and Meetings Sub-Committee and to the Visits Sub-Committee for their excellent arrangements, both in regard to Syllabus as well as to social functions.

A portion of the library has been transferred (on loan) to the Cumberland Sub-Branch and their Secretary reports on its utility. Further Reports of the Safety in Mines Research Board have been added during the year, and Volumes 1—5 (1925-1929) have been bound and are available to members.

The Branch Committee record their best thanks to the Council of the North of England Institute of Mining and Mechanical Engineers and to the Governors of the Workington Technical School for the privilege of the use of rooms for meetings. They also thank the Governors of Armstrong College and Prof. W. M. Thornton for the use of his room and for his services for the Certificate Examinations.

The Branch Committee further place on record their appreciation of the privileges and entertainment accorded to the Branch at the several places visited by members.

The report of the Cumberland Sub-Branch was read and it was adopted. On the motion of Mr. Shatford it was agreed to convey to Mr. A. R. Hill, the Hon. Secretary of the Branch, the thanks of the North of England Branch for the work done on the West coast.

Election of Officers.

The result of the ballot for Office Bearers for Session 1931-1932 was:

Branch President: Mr. Sidney Bates (Chief Mining Engineer of the Mickley & Associated Collieries).

Senior Vice-President: Mr. Sy. Burns.

Second Vice-President: Mr. W. L. Tulip.

Honorary Treasurer: Mr. E. E. Shatford.

Honorary Secretary: Mr. S. A. Simon.

Ass. Hon. Secretary: Mr. R. G. Wilson.

Four Members of Committee: Messrs. R. W. Mann, Geo. Mann, T. Davis, and F. Bailey.

Mr. H. J. Fisher, retiring President, inducting Mr. Sidney Bates to the Presidential Chair, mentioned that he had done a large amount of work in connection with the electrification of collieries. Mr. Bates having been welcomed with enthusiasm, suitably replied, and moved a hearty vote of thanks to the retiring President, Mr. Fisher and also to the other office bearers and members of the Committee who had worked along with Mr. Fisher.

Mr. Fisher in reply stated how much he appreciated the hearty vote of thanks accorded to him.

Lighting of Mines.

A discussion on the draft proposals issued by the Mines Department regarding amended regulations for Lighting at the Coalface and other parts of the mines followed.

An Address by the President of The Association

J. W. GIBSON.

It is indeed a pleasure to me in visiting my native heath to meet so many old friends, particularly an old friend, a Member of this Branch, who gave me my first start as a colliery electrician, going back, most of you will say to ancient history, over 35 years ago.

It is an interesting coincidence that the Coming of Age of the Association synchronises with the Faraday Centenary. The Association has completed 21 years of service in the interests of Mining Electrical Engineering, and in the service of the Industry, and I think we can claim some progress in the direction of establishing the status of Mining Electrical workers. Their experience, study and training is now receiving official recognition. Your Association has been invited by the Mines Department to give their consideration to the question of qualifications of Mining Electrical Engineers and Colliery Electricians, who are responsible for the safe operation of electrical apparatus above and below ground, and it is possible that these investigations may lead to compulsory certification.

It is therefore more than ever necessary that those who aspire to posts of responsibility in future should take full advantage of technical education facilities and prepare themselves for the opportunities which are sure to arise. Remarks are often made to the effect that all the good posts are already filled, and that evening work and study are scarcely worth while. That view is entirely wrong. The younger men usually have only knowledge of local opportunities. In my personal associations with mining work in other parts of the world, I can say with confidence that in every case I have had to deal with men, British engineers, most of whom were trained at home. There is a preference abroad for the British trained mechanical and electrical engineer. There is a big world of opportunity available, and it is the duty of the young man to qualify, not only to discharge fully his present duties, but to prepare himself ready to take full advantage of opportunities when and as they will most certainly arise.

Michael Faraday came of very humble parents. His father was a country blacksmith, and Michael Faraday as a youth worked in a humble capacity in a Bookseller's shop, where he apparently had the opportunity to satisfy his thirst for knowledge by reading, and he gradually qualified for something very different. He was ready when in due course there came his opportunity to join that brilliant scientist, Sir Humphrey Davy. That was the real commencement of the brilliant scientific career of Faraday, which has meant so much to all of us, and particularly to electrical engineering.

Just in passing it has occurred to me that reference to Sir Humphrey Davy is a reminder that one of the first Davy Lamps tried underground in a gassy mine, was tried on Tyneside at Hebburn Colliery.

One of the principal objects of our Association is to encourage educational facilities, and in this direction substantial progress has been made by the preparation of a syllabus of instruction suitable for Mining Electrical Engineers, and which has been circulated for the attention of Technical Education Authorities. By the adoption of this syllabus we are hopeful that a larger number of men will take up technical studies in their spare time, and qualify by taking the Association's Certificates.

If, in the near future, compulsory certification is adopted, there will probably be a sort of inter-period before qualifications can be clearly defined and official or statutory certificates of qualification issued. In the meantime, the Association's Examination Certificate will at least serve the purpose of acting as an indication that the holder has qualified to a recognised degree, by technical education and study.

In the last few years there has been much to discourage in the condition of the Coal Mining Industry. It has even been suggested that no useful purpose can be served by spending time in study to qualify for positions in an industry which appears to be declining rather than improving. The Coal Industry is unlike many others, inasmuch as it is fundamental. Coal is a fundamental necessity to nearly every industry, and whilst it may contract due to trade depression, it cannot fade out of existence. Coal will always be the fuel of major importance to this country.

Three or four weeks ago I heard of the closing of one of the mines in this district, which I understand has been working for 276 years and, with the exception of strike stoppages, has been drawing coal for practically the whole of that time. An attempt has been made towards electrical equipment, but this had not been carried out completely for the reason that the mine was an old one. I think you will agree with me that a mine of its age might be considered redundant, and energy and capital deflected in the direction of new pits.

Our electrical power stations which were thoroughly up-to-date twenty years ago, are now looked upon as uneconomical, and are being replaced by stations of entirely different design as regards combustion, steam pressure and temperature, and size of generator units

If there is very little shyness or reluctance in scrapping electrical plant which is considered out of date with twenty years' service, there is surely sufficient justification for the cutting out of a lot of the "old wood" in the mining industry which is now being done and, by concentrating on greater output capacity at thoroughly up-to-date mechanised and electrified collieries, the Industry should within the next two or three years, develop a new lease of life. This will be all to the benefit of the Community in general, and to Electrical Engineering and Mining Electrical Engineers in particular.

I think our Association can look back on good work well done, and also to the future with full confidence, for Mining Electrical Engineering has become of real and vital importance to the Industry.

SOUTH WALES BRANCH.

Earthing of Electrical Apparatus.*

Discussion.

Mr. W. W. HANNAH suggested that for a super power station the geological selection of good earthing places was so unnecessary that even two threepenny pieces might be considered as ample for artificial earth plates because, provided there was good bonding, the plant would be well earthed by the multitude of pipe connections, foundation bolts and unavoidable connections to steel structural work which would exist throughout such a station.

Good bonding of all iron and steel work enclosing electrical gear and cables was absolutely essential, but the need for artificial earth plates surely existed much more in the small power station or in very small outlying substations.

Mr. Hannah recollected a case in which an underground system was being changed over from an unearthed to earthed neutral by earthing the middle point of a transformer. In order to test the efficiency of the leakage protection gear a deliberate earth was put on one phase of a motor stator and the controlling switch closed. The connecting cable from the motor back to the substation flashed over at joint boxes and where the cable lay against steel arches. The bonding glands had become dirty and corroded and there was not proper continuity of the earth return. When those defects were remedied all arcing disappeared. He would suggest that good bonding was the most essential feature on all installations, and that artificial earth plates were not of great importance save on small installations.

Mr. F. C. KNOWLES as a member of the London Branch expressed his pleasure in visiting his colleagues in South Wales. He congratulated Mr. Vaughan Harries, who had evidently taken a great deal of care and trouble in making tests over very long periods. The references he had made to those tests in his paper would represent only a very small fraction of the work that lay behind them. Mr. Knowles could speak feelingly as one who also had carried out a great many tests and he appreciated that the Author had had to overcome very many difficulties.

When testing earth, whether testing a body of earth in a mass buried in mother earth, or in a box, it cannot be treated as a homogeneous resistance like a metal plate or metal block. It was in effect a series or multiplicity of contacts which were very indefinite. In the tables which Mr. Harries had given, attempts to apply Ohms Law would fail. For instance, values for clay were given, water was added to it, the resistance of the water was given, but a calculation of the combined resistance of clay and water would not agree with the test results. Instead of the water being 660 ohms per cubic feet, it should be more of the order of about 400 ohms to the cubic feet. Resistance measurements when dealing with earths, were quite beyond the power of calculation and with all due respect to the author, Mr. Knowles said he did not believe in the efficiency of measuring the resistance of earth by means of a small sample of earth taken in a box or anything like that. This contention was substantiated by exhaustive tests which had been carried out by the Bureau of Standards in America. Samples of earth were no criterion for the main body of the earth: moreover, seeing that today there were instruments available which would test earth in various ways, he could not see any reason why it should be done in that way piecemeal by sample boxes. It must always be remembered that the mass of the earth was under very great pressure.

Recently, experiments had been carried out with regard to the thermal conductivity of the soil. The results of those researches were not yet published but they shewed that when down to 10, 15 or 20 feet below the surface, the current carrying rating of cables was nearly 20% higher than if they were near the surface or within two or three feet of ground level. That was explained as being due to the fact of pressure which resulted in the closer thermal contact of the cables with the particles of the soil. Consequently the conclusion which had been arrived at during the past few years was that to gain an adequate artificial earth, the earth plate should be buried deep to ensure constant pressure and contact. Furthermore, at considerable depths the moisture content was practically constant. In this country, surface conditions were generally such as not seriously to affect the results, but they were very important in many countries. Only recently a large number of tests were carried out in Canada where the soil was of very low resistance in the summer but which in the winter was practically an insulator, owing to the fact that it was icebound; at a depth of 20 feet or so an adequate earth was obtained.

In his paper the author had stated that the resistance was the contact between the metal of the earth plates or pipe, and the soil. That was not in accord with tests carried out, both here and in America, which shewed that the immediate contact resistance was higher in proportion than the resistance of the subsequent layers of earth. The figures obtained from coke were very extraordinary, and particularly so in the case of dry coke. The addition of water increased the conductivity: the resistance fell, but Mr. Harries had shewn in his discourse that it went up 50%; also in his layout of the ideal earth plate, he shewed that he added water to the coke. Why water the coke if the dry was better than the wet? As a matter of fact wet coke was a better conductor than dry coke. In Mr. Knowles' opinion the coke was only used because it helped to increase the contact area of the earth plate with other earth in a cheap way. If large earth plates could be made cheaply there would be no need for coke, the earth plates would make contact with as large a mass of earth as possible.

The figures the Author had given for clay with salt solution were not at all surprising, because there again, salt was a comparatively good conductor. Clay soaked in sea water would give a very much lower resistance but that was not a general practical proposition because of corrosion. In America, there were salted "grounds", and in many places it had been found necessary to examine the earth plates every year or two and replace them.

Dealing with the function of earth plates, Mr. Knowles said he was interested in the Chairman's remarks; but Regulation have to be complied with and they insist on earth plates. The function of earth plates, in the speaker's opinion, was to prevent a potential rise, they only being called upon to carry current for a small portion of their life. When putting down earth plates, he believed it was quite common practice in collieries and other places to duplicate them, and although they were working in parallel they were tested in series.

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* See *The Mining Electrical Engineer*, April, 1930, p. 362 and May, 1930, p. 375.

He would here interpolate a word of caution ; the plates should be put far enough distance apart so that the resistance areas of the plates did not overlap, in order to obtain the greatest earthing efficiency. For instance ordinary plates four feet by six feet should be at least ten feet apart.

With regard to the remarks that when putting down a station adequate attention was not paid to the geological structure of the site, there was a place for both Mr. Harries's and the Chairman's remarks. No one would consider the nature of the sub-soil, as an electrical conductor, as a deciding factor from the commercial standpoint: but where earth plates were required it was always advisable to explore the ground and select the best and right place.

Mr. Knowles said he had met cases where it had only meant moving the position of an earth plate a matter of six yards in order to get a good earth. In one case by moving the position from one side of a substation to the other side a good earth was secured.

As Mr. Harries had pointed out in his paper, the Megger Earth Tester not only enabled the actual resistance of an earth plate to be measured, but also the specific resistance of the soil and so it provided every facility for enabling investigations to predetermine the best position for placing earth plates.

With regard to the question of insulation testing Mr. Knowles mentioned that there were insulation testing sets now available with hand generators which developed testing pressures up to 2500 volts. The author had referred to the testing of insulation when warm, Mr. Knowles suggested that the test be made not only when it was warm but also when it was cold, as the two tests would together reveal the leakage due to compensation and also service troubles.

Mr. W. S. RICHARD congratulated Mr. Harries on his very able paper. The results of the author's experiments and tests were very useful. Emphasis had been laid on the knowledge of the geological features of the neighbourhood where it was proposed to erect a power station. In collieries the nature of the ground could easily be found on referring to findings when the colliery was sunk in the first instance.

In his remarks on the earth strata, Mr. Harries' general assumption of stratified formation was correct, but there were differences. In the anthracite coalfield, for instance, all shales were high in ironstone concretions, or in definite and persistent layers of ironstone bands, thus its mass conductivity would be high. Sandstones again were usually waterlogged and formed good reservoirs of water. Fireclay was also high in metallic content containing nodules of ironstone.

With reference to earth plates, Mr. Richards would have liked to learn that the author had carried his experiments a little further, and had taken into consideration the conical type of earth plate, as recommended by Dr. Thornton. In some of the collieries with which he was connected Mr. Richard stated that he had put into commission several earthing systems composed of pipes, as mentioned by the author, and they had given satisfactory results. On the pipes, copper bars were used and installed around the whole of each of the pipe flanges, the copper bar being tinned so that the contact resistance was reduced to a minimum. In some cases they had had to get down to a considerable depth before anything like results were obtained. He had also experimented with salt, etc., but could not recommend the practice.

The question of periodic testing was an important one, Mr. Richard said he understood that the provision of a Chart Recording Earth Leakage Indicator was now being recommended by the Mines Dept. The author had recommended the double-pressure test before putting apparatus into service: that would certainly give some assurance as to the state of the apparatus, but one could not deny that damage might also be caused through increased stresses on the dielectric.

Again, with reference to earth continuity testing of cables etc., on a large underground system, the method described by Mr. Harries took up a very considerable time; switchgear had to be dismantled at the various sub-stations etc., in order to get at the cores of the cables. Where a telephonic system was installed, as was usual between sub-stations, it would be quite simple to utilise the telephone cable between point to point by connecting it, through suitable isolating switches, on to the armouring of the cable under test. Of course, resistance of the core of the cable would have to be measured in the first instance. That method would do away with a good deal of the dismantling of switchgear for the measurement of armoured cable continuity.

In one of his sketches Mr. Harries had shewed a flame-proof tank, and also washers between flanges to create a vent. Do not those vents make the tank non-flame-proof?

Re M.D. Circular No. 23, Mr. Richard said he would have liked the author to deal further with the matter, especially as in the Annual Report for 1929 Mr. Horsley had included an Appendix on this subject for the guidance of all electricians. Mr. Richard believed that manufacturers were getting down to this question and that switches could now be obtained with this feature as a permanent and integral part of the switch. Still, as the author had indicated, existing switchgear would have to be considered. The cost of erecting this provision would increase the cost of a switch by approximately 20%.

Mr. J. B. J. HIGHAM.—Although certain test results as given by Mr. Harries were not quite in accordance with what other investigators had determined, and in the case of wetted coke the result appeared contradictory, they did give some guidance as to what variation of resistance to expect with soils containing various quantities of moisture. Mr. Higham was doubtful whether absolute values, if they could be obtained, would be of any greater use to anyone. The author had in any case attempted to get conditions that obtained in practice.

Mr. Higham said there did appear to be some discrepancy in the figures given in Table I. Referring to the case of wetted coke: the author had suggested that the increase of resistance was due to the presence of water between the particles of coke. It was noticeable that in all other cases by the presence of water the resistance was reduced. The conditions were very interesting and, provided that coke was free from sulphur and very clean, Mr. Higham believed the author's suggestion was probably correct. The added water would undergo no change in resistance unless a chemical change occurred. Absolutely pure water had an infinite high resistance, but with very small amounts of impurities its resistance was reduced considerably—in fact, enormously. The addition of a very small amount of acid definitely produced ionisation of water and as a result it had a very much lower resistance: as an example, the strongest sulphuric acid could be carried perfectly safely in iron drums or tanks, but when diluted it was highly corrosive. During the war a large quantity of sulphuric acid was shipped from America to this country; no trouble was experienced until certain unscrupulous shippers, thinking to profit by adulteration of the acid, diluted the acid to such an extent that the bottom of the ship was practically eaten away. Luckily the ship made port before a serious leak started but the whole of the ship's under water plates had to be replaced.

When water is added to clay it would dissolve certain salts and as a result its resistance would be reduced. In all such cases there was sure to be a better contact between particles of the substance, giving a greater effective cross sectional area and hence a lower resistance. The object of keeping a large area of ground around an earth plate in a moist or wet condition was to increase the effective area for the passage of earth currents. Although the figures given may not be a true representation of the actual condition, they gave comparative results which were at least instructive, if not of immediate practical value—although in Mr. Higham's opinion they were of considerable value.

Under the heading of motors, the author had given a record of insulation tests (Fig. 5), and stated that the difference was due to change of temperature. That was typical of all apparatus which had insulation with a fibrous basis. A paper was read before the I.E.E. some years ago by two Metropolitan-Vickers engineers and they made reference to that fact. A reprint of the graphs and a note on the subject were to be found in a brochure published by Evershed & Vignoles. Mr. Higham was interested in this matter, because he had been entrusted with making the tests in the first place. There had been trouble with the breakdown of transformers on the one-minute over potential test after what was considered to be a perfect drying out. It was found however that in some cases the transformer was in a worse condition at the expiration of the normal drying out period than when cold from store. The explanation put forward by the authors' of the paper mentioned was that the more or less confined or localised moisture within the transformer when cold from store was vapourised and distributed throughout the windings by the heating, and hence gave a large number of parallel leakage paths. The insulation resistance would naturally be much lower and the transformer more liable to breakdown. The same would apply to any motor or generator. The only course to adopt therefore was to continue the drying out process until the distributed moisture was completely driven off and that could be determined by reference to Megger readings taken during the drying out. After the initial fall of insulation resistance there was very little, if any, change for a matter of hours—depending on the type and size of transformer—but once the insulation resistance began to rise the drying out was completely effected in a comparatively short time.

The matter of drying out would therefore appear to be a simple matter, where the Megger was used in conjunction with the process, and it was perfectly safe to apply the over-potential test or put the apparatus into immediate service after the "flash" test if the Megger readings were well on the rise. In certain cases in mining work it might happen that machines had to be rushed into service without drying out but if time was available to dry out, then it should be done properly. It was possible for a machine to stand normal voltage or more when cold from store and yet to breakdown on a "flash" test when just warm, at a potential lower than the normal working pressure of the machine.

(*To be continued*).

Association of Mining Electrical Engineers.

EXAMINATION PAPERS, 1931.

FIRST CLASS CERTIFICATE.

(*Continued from Page* 79).

3.—*Electric Lighting and Signalling.*

(1) Define the terms "mean horizontal candle power," "mean spherical candle power," "foot candle," and "lumen."

Describe how the candle power of a lamp is determined in practice. How do variations in voltage affect (a) the illuminating power, (b0) the efficiency, and (c) the life of a lamp?

Under what basis is the efficiency of electric lamps assessed?

(2) Describe the arrangements you would make for underground lighting when the following supplies are available at a pit bottom sub-station:—

(a) Three-phase current at 3000 volts.

(b) Direct current at 500 volts.

(3) A main roadway 1000 yards long is to be lighted by 60 watt, 100 volt lamps fixed at intervals of 30 yards. At the inbye end of the roadway is a junction and an engine house each requiring two lights. Assuming a maximum current density of 1000 amperes per sq. in., find the size of cable to be installed. If the resistance of copper is 0.66 microhms per inch cube, find the resistance of the cable and the voltage drop at the end of the cable.

If the lamps are lighted for 12 hours per day for 300 days per annum, and the cost of current is 0.5d. per unit, find the cost per annum of current for lighting the roadway. What difference would it make to your answer if the current were fed in at the middle of the lighting circuit from a power cable? (neglect the voltage drop in the power cable.)

(4) Sketch and describe (a) a trembler bell, (b) a single stroke bell, each suitable for use in a coal mine.

Under what circumstances would you use these different types of bells?

(5) Discuss the merits and demerits of a central battery system for signalling purposes at a colliery. Describe a typical lay-out of the signalling arrangements for a large mine.

(6) What are the requirements of the General Regulations respecting the use of telephones in mines? Explain how a telephone works and describe a telephone suitable for mining use.

(7) Outline briefly the differences between a primary cell, a lead acid accumulator and an alkaline accumulator.

For what purposes are each of these used in and about mines?

Give typical charge and discharge curves for the two types of accumulators. What tests should be applied to an accumulator to determine its general condition?

(8) Sketch and describe a suitable lighting arrangement for underground stables to accommodate 40 horses. The stalls are each 9 ft. × 6 ft. and a tub road 6 ft. wide runs the whole length. Current at 105 volts is available.

Details must be given as to the type and number of lamps, the size and type and method of supporting the cable and the switching arrangements.

4.—*Electrical Regulations and Special Paper.*

(1) What are the requirements of the General Regulations in respect to earthing of electrical apparatus? Sketch and describe a suitable earth connection for colliery purposes and illustrate the arrangements you would instal for periodically testing the same.

(2) What do you understand by the terms "open sparking," "flame-proof enclosure," "low pressure," "medium pressure," "high pressure," and "extra-high pressure"?

What limitations are imposed by the General Regulations upon the use of pressures higher than medium pressure?

What procedure is necessary before electricity is introduced into a mine? Does this apply to all types of electrical apparatus?

(3) Under what circumstances must the supply of electricity be cut off in a mine?

Outline a scheme of inspection for coal face machinery, beginning from the gate-end box and enumerate the various points to which attention should be directed.

(4) What are the provisions of the General Regulations with respect to trailing cables?

What special dangers attend the use of trailing cables? Describe a type of trailing cable suitable for supplying power to a three-phase coalcutting machine.

(5) Enumerate the various testing instruments which form part of the equipment of a colliery electrical department. Indicate their various uses and the requirements of the regulations in respect to those which are provided in compliance therewith.

(6) Describe the method you would adopt to lower a cable into a deep mine shaft and explain how the same would be supported. What provision is necessary where the same shaft cable supplies two mines at different levels?

(7) A new oil switch is required for a duty which you may assume but must specify in your answer. Indicate the data you would supply when requisitioning such a switch. To what tests would you subject the switch when received in order to satisfy yourself that it would meet the requirements?

(8) An output of 90 tons of coal per hour has to be hauled by endless rope from a roadway 2000 yards in length having an adverse gradient of 1 in 10. The tubs weigh 6 cwts. and carry 12 cwts. of coal and are to be run in sets of 4. The speed of haulage is to be 2 miles per hour. The rope is $\frac{7}{8}''$ in diameter and weighs 4 lbs. per yard. Assuming that the co-efficient of friction for the tubs is 1/56 and for the rope 1/20, calculate the B.H.P. of the motor required for this duty.

Assuming also that three-phase current at 550 volts is available indicate the type of motor you would instal. If the motor efficiency is 88 per cent. and the power factor is 0.88 find the full load current per phase.

HONOURS EXAMINATION.

Paper No. 1.

(1) What is the chief electrical problem involved in the design of a large electrical winding engine? Describe the various methods adopted in practice to solve this problem and give a sketch of the layout of one type of electric winder shewing the connections.

(2) Calculate the cross sectional area of copper conductor for the most economical transmission of 1000 k.w. by three-phase current over a distance of 5 miles at a pressure of 10,000 volts. For the purposes of arriving at your answer reactive effects may be ignored and the following assumptions should be made.

Price of copper = £70 per ton.
Cost of energy = 0.2d. per unit.
Specific Resistance of Copper = 0.7 microhm per inch cube.
Interest and depreciation = 6 per cent. per annum.
Working hours per day = 12.
Working days per year = 300.
Weight of copper per yard per sq. in. section = 11.58 lbs.

What materials other than copper are used for overhead lines and what advantages accrue from their employment?

(3) It is found necessary to increase the available electric supply at a colliery by 1000 k.w. Draw up a scheme for one of the following cases:

Case I. A regular supply of coke oven gas having a calorific value of 450 B.Th.U's. per cu. ft. is available up to $1\frac{1}{2}$ million cu. ft. per day.

Case II. Exhaust steam up to 34,500 lbs. per hour is available for 8 hours per day.

Assume in each case that the new plant will require to run at full load for 8 hours per day and at half load for the remaining 16 hours per day.

N.B.—Only one case to be dealt with in as much detail as time permits.

(4) Draw a diagram of the connections of a motor starter suitable for a 25 h.p. 250 volt shunt motor shewing overload and no-volt releases. Explain the considerations that govern the total value of the resistance, its current carrying capacity, and its sub-division between the various steps of the starter.

(5) What are the factors which determine (1) the torque exerted by a motor and (2) the speed at which a d.c. motor will run?

A 400 volt d.c. shunt motor has four poles, 700 armature turns and is lap wound. If the flux per pole is 2.5×10^6 lines and the armature resistance is 0.3 ohm, determine (1) the torque, (2) the speed and (3) the horsepower developed when the load is such that the armature takes a current of 25 amperes.

(6) How is the danger of open sparking eliminated in bare-wire signalling systems used in coal mines?

Describe a method of signalling in which the presence of make-and-break sparks is avoided. What are its advantages and disadvantages?

(7) What are the requirements of the general regulations with respect to shot-firing circuits and shot-firing cables?

What are the permissible sources of electric current for shot-firing?

Describe a magneto exploder for firing shots in mines. What factors influence the firing efficiency and the safety of exploders?

How are such appliances made inherently safe?

Paper No. 2.

(1) What do you understand by the term "wave form of an alternator"? What is the ideal wave form, and what methods are adopted in the construction of alternators to attain this?

Describe briefly an instrument which may be employed to determine the wave form.

(2) Explain by the aid of diagrams, the methods you would adopt to measure the power in a three-phase circuit (a) by a single reading of one wattmeter, (b) by two readings of one wattmeter, and (c) by the use of two wattmeters.

Shew how you would obtain the power factor from your readings in case (a). Under what circumstances is this method inapplicable?

(3) Discuss the economics of power factor correction. Assuming that additional generating plant may be installed at a cost of £x per k.v.a. and that the cost of phase-advancing apparatus is £y per k.v.a., deduce an expression for the economical limit of power factor correction.

If the value of x be 8, and the original power factor 0.71 (lagging), find the limiting value of the cost per k.v.a. of phase advancing plant which would warrant the power factor being raised to 0.8 by this means.

(4) Enumerate the various losses which are inherent in the transformation of electric energy by:—

(a) static transformers.

(b) rotary converters.

Indicate the usual magnitude of the individual losses and how they are kept down to a minimum in practice.

(5) Describe, by the aid of diagrams, the cascade method of control for induction motors. What are the advantages of this method of control and for what purposes is it applied to colliery plant?

(6) It is required to instal a 120 k.v.a. three-phase transformer for stepping down from 3300 volts to 550 volts in a pit bottom sub-station. Draft a suitable specification for this unit. What tests would you carry out to ascertain that the transformer was in order after it had been installed?

(7) A large three-phase 3000 volt induction motor is used to drive the ventilating fan at a colliery and takes 640 k.v.a. from the line at a power factor of 0.7 (lagging).

What must be the k.v.a. rating and the total capacity of a bank of condensers so that the power factor is brought up to 0.9?

Shew clearly by a diagram how the condensers are arranged and connected to the circuit

Approved Flame-Proof Gear.

The Mines Department have recently written to the British Electrical and Allied Manufacturers' Association the following explanatory notes concerning "official certificates for flame-proof electrical apparatus."

A number of inquiries having been received as to the validity of Sheffield University certificates now that official certificates are being given by the Mines Department on the basis of official tests, it may be useful to give you the following explanation for communication to the members of your Association if you think desirable.

The types of electrical apparatus tested formerly by Sheffield University and now by the Mines Department embrace (*a*) mining apparatus and (*b*) apparatus for other uses.

With regard to mining apparatus, Sheffield University certificates are recognised and accepted by the Mines Department as *prima facie* evidence that the certified apparatus is flame-proof.

In the further matter of general safety design and construction, apparatus covered by a Sheffield certificate is usually such as the Mines Department would be prepared officially to approve and certify, but this will not necessarily be so in every instance. Knowledge has advanced and design improved since testing work was started at Sheffield nine years age—partly as a result of that work—and it will be necessary therefore for the Mines Department to review each case on its merits before an official certificate can be granted as the full equivalent of a Sheffield certificate. In many cases—and more particularly with Sheffield certificates of recent date—it will probably be possible for this to be done without further tests by examination of the apparatus or of specifications and drawings of it, and in that event the fee charged would be nominal.

The same rulings apply and the same procedure will be followed with regard to apparatus for factories, petrol stores, etc., and the standard of requirements to be applied will, by arrangement with the Home Office and Board of Trade, usually be the same as for mining apparatus.

Coal Face Machinery Exhibition:

SHEFFIELD: 2nd—10th October, 1931.

Several of the principal exhibiting firms have sent us preliminary details of the plant and equipments they are to display on the floor of the Drill Hall, Sheffield; as a consequence intending visitors can be assured that there will be no lack of interest and that they will be afforded a most valuable insight into the very latest developments of engineering practice at and near the coal face. There has never been before available such a straight-forward opportunity for readily comparing the respective capabilities and merits of the plants and methods advocated, in competition, by all the leading British manufacturers engaged in this highly specialised business. Full publication of the more notable features of the exhibition will of necessity need to be deferred until the show is the accomplished fact, but the following brief outline of promised exhibits possessing distinctive electrical features will indicate the great importance of this imposing attempt to speed the wheels of the British mining industry.

ANDERSON, BOYES & Co., Ltd.

This Company are to have on view a range of their well-known coalcutting machines which includes coalcutters of their very latest development, and which shew the extraordinary advance made in the design of coalcutting machinery within recent times. Several complete machines are to be on view, as follows:

The "A.B. Twelve" Electric Coalcutter, designed primarily to meet the demand for a machine capable of tackling effectively the thinnest workable seams, is of the three-unit design, steel-clad from end to end. The leading dimensions of this machine are 7 ft. 9 ins. long × 2 ft. 2 ins. broad × 12 ins. high. Ball or roller bearings are employed throughout and special provision has been made for thorough lubrication of all working parts. The motor is of the squirrel cage type, 30 h.p. The switch of the A.B. patent star-delta barrel type which is housed in the motor compartment. An air motor of the turbine type can be fitted in place of the electric motor when the power supply is compressed air. The haulage is of the rope type having a large diameter vertical rope drum. A spring-loaded friction clutch is incorporated in the gear train to safeguard the machine and protect the mechanical parts. A release gear is also embodied to facilitate the running out of the haulage rope. The gearhead houses the reduction gear between the motor and the cutting chain and facilities are provided for putting the cutting chain out of action.

The "A.B. Fifteen" Electric Coalcutter meets the demand for a machine capable of cutting the hardest of cuttable subjects. This machine presents many outstanding points which will immediately appeal to mining men. It is of remarkable power for a machine with such low overall dimensions: 7 ft. 7 ins. long × 2 ft. 2 ins. broad × 15 ins. high. The motor is 50 h.p., squirrel cage and the switch, star-delta, is housed in the motor compartment. An air turbine motor for this machine and also an electric motor for it are to be shewn separately. The haulage is of the rope type of unique construction, which allows the advantage of rope haulage being obtained while avoiding the disadvantages frequently encountered in haulages of this type. A variable cutting speed and also a fast flitting speed are provided, both drives being transmitted through a multi-plate friction clutch which gives rapid and easy control. To facilitate the running out of the haulage drum a release gear is embodied. The machine carries a very large reserve of power which may be called upon with perfect safety as required.

The Anderson Boyes Arcwall Coalcutter maintains the features of attractive form, simplicity, accessibility and robustness of all the A.B. machines. The advantages of maintaining the machine on the rails for all duties are now generally appreciated, and the facilities provided on this machine for staying or propping in the headings in the least possible time and with the smallest amount of effort, together with the convenience and ease of control, make it an ideal tool for giving an arcing cut into the solid under conditions suitable for this form of kirving. The machine is mounted on a self-contained power-propelled truck and, as arcwalling put very severe stresses on the gearhead, the machine is equipped with a gearhead specially designed to suit the arcwall system of cutting and which enables the jib to be swung through a large arc.

The A.B. Patent Universal Heading Machine is a unique machine of the arcwall type, and it is claimed to represent the most outstanding advance that has taken place in coalcutting machine design for many years. The machine, as its name implies, is a heading machine and it is capable of holing in any position from floor level or at any intermediate height up to 4 ft. 6 ins. above floor level. It can also shear in any position within the same limits. In addition the machine can cut on the inclination of the seam and make a shearing cut either vertically or at any angle. All the controls are grouped at the driver's end of the machine and stays are provided for fixing the machine in the place with the least effort and in the shortest time. The jib is slewed or swung by totally enclosed direct gearing. The claims for this new machine are that it facilitates the work when cutting close to rail level or when taking a pavement brushing, allows a holing to be made at floor level, provides for adjustment to a variable cutting position, and, further, combines a holing and shearing machine in one compact unit. The versatility of this machine needs to be seen to be appreciated and, as the machine will be running under power on the Stand, an opportunity will be afforded of seeing it in action.

Anderson Boyes & Co. Ltd. are also to shew a gate-end distribution circuit breaker board comprising five panels suitable for controlling two coalcutters, two conveyors and a gate-end loader. The circuit breakers are of the air-break type: the small one controlling the loader is of special design to meet a long-felt want for small power circuits such as gate-end loaders. The board is of unit construction, the cases being built up of strong steel plates welded together and having wide machined flanges rendering them flame-proof in compliance with the Regulations under the Mines Act. The incoming way to the board is arranged for armoured cable, and the outgoing ways are by A.B. B.E.S.A. plug and socket connections, the small panel being fitted with a gland suitable for taking armoured cable.

There will also be shown a selection of B.E.S.A. trailing cable plugs and sockets arranged with the various fittings which can be supplied for special conditions.

A Two Panel Metro-Vick Remote Contral Gate-End Breaker is used to control the "A.B. Fifteen Coalcutter" which is arranged for remote control. Other exhibits of Anderson Boyes & Co. Ltd. are a Shaker Conveyor Driving Gear and a Scraper Loader Driving Gear.

MAVOR & COULSON, Ltd.

The general arrangement of this display includes four representatives types of coalcutters in the centre of the stand and around them conveyors, loaders, and switchgear. On one side will be shown an equipment for mechanical loading on longwall faces, working on the buttock: the coal being picked up by the loader and delivered into a travelling hopper on the belt conveyor.

The M. & C. Joy Loader is to be seen for the first time in Great Britain. Two gathering arms feed the coal on to the conveyor, the rear portion of which can be swung 45 deg. to either side by hydraulic jacks. Other jacks raise or lower the rear part of the conveyor, and raise the gathering head for flitting. The caterpillars have change gear for two speeds. One electric motor drives the whole loader, and runs in one direction all the time. The loader is guaranteed to load 1½ tons per minute in loose coal. Its height is 3 feet, its length 20 feet, its weight 4¼ tons; it is compact and light relative to the work it performs. It delivers to a hopper, which loads the belt centrally and gives the coal its correct initial speed. The hopper is carried on rails, along which it can be pushed by the loader itself. The rails are dropped into sockets on the feet of the belt conveyor structure, which holds them securely at the correct gauge. The troughed belt conveyor, specially made for face use with the Joy Loader, is only 13½ inches high; the joints allow rapid coupling together of the sections, and ensure alignment of the conveyor. Inverted troughing forms a light rigid structure which supports the belt-carrying idlers and protects the return belt.

The M. & C. Arcwaller Coalcutter has a jib which can be slewed at any speed up to the maximum without the use of a rope. The wheels are mounted on a rollers stand to show the flitting and sumping speeds and the action of the reverse gear. Every provision is made for rapid cutting and flitting, and all controls are under the hand of one operator. Duplex picks allow a place to be cut in either direction; they save the time of turning the picks, and cut twice as many places as single pointed picks.

The Samson, H model, coalcutter to be shown is an air-driven machine arranged for longwall work. This machine has established itself in nearly every important coal mining country, including U.S.A.: it is claimed that it can cut the hardest holing that picks can cut, and cannot be overdriven.

The Low Seam Samson, M model, coalcutter is 12 inches high, yet is said to have the power and cutting capacity expected of a full size coalcutter. The ten-speed haulage, giving from 10 inches to 20 feet per minute, under complete and effortless control, gives adjustability to suit all conditions of cutting and manœuvring. It makes a thin cut or kerf of 4 inches, or a thick kerf of 7 inches high.

The 12 inch Bar Coal Cutter has the same totally enclosed haulage as the Low Seam Samson; it is 6 ft. 8 ins. long, and will undercut to eight feet deep. The bar can be raised, lowered or tilted, to follow irregularities in the seam or in a band.

An M. & C. Electric Driving Gear coupled to M. & C. Shaker Conveyor Troughing is to be shown. The height of the gear is 16 inches; lubrication is automatic, a stream of oil thrown up by the gears being directed to each bearing. The powerful kick may be modified where the work is light. The trunnion mounting allows the gear to run slightly out of line with the troughing. Lightness combined with strength and durability are features of M. & C. troughing. The steel used for each part of the trough is the best obtainable for its own purpose, and is British made. The troughs are joined by the M. & C. Ritchie Joint, a joint that can be made and uncoupled in four seconds. It can be uncoupled from the face side without touching the goaf side. It keeps tight during use, and does not develop backlash.

The Shaker Conveyor is to be placed to feed a Troughed Belt Gate-end Loader. The Loader is controlled from the outbye end of the jib. A step-down transformer connected to it supplies a face-lighting equipment.

An M. & C. type A202 air-break remote control gate-end circuit breaker is to start and stop the Arcwaller. A series isolating and reversing switch with auxiliary control switch is fitted in the machine, all circuit closing and opening taking place automatically at the gate-end circuit breaker.

A type A141 gate-end circuit breaker of the flameproof oil-immersed a.c. automatic type 100 amps. capacity, mounted on skids, is to control the Joy Loader; it has been specially designed for mining conditions and has novel features in addition to those which efficiently protect the machine from excessive or continuous overloads and the effects of misuse.

Other M. & C. exhibits will include: a flame-proof oil-immersed gate-end circuit breaker of smaller capacity also skid-mounted, and suitable for the control of conveyors and other machines of a similar duty: a flameproof air-break non-automatic gate-end switch fitted with B.E.S.A. plug and skid mounted: a gate-end switch fitted with M. & C. standard flat plug: an air-break remote control gate-end circuit breaker, provided with leakage protection and testing equipment: a three-panel flame-proof oil-immersed distribution board for controlling coalcutter and conveyor circuits, comprising a cable box for an incoming supply and two draw-out type feeder panels and one non-draw-out panel: a three-panel oil-immersed conveyor control unit, skid mounted, suitable for such use as with one gate-end loader and two conveyors.

USKSIDE ENGINEERING Co. Ltd.

Examples of equipment to be exhibited by this Company include: an Electric Chain Coalcutter, fitted with 5 ft. 0 ins. jib, arranged for cutting at floor level: an Electric Jigger Conveyor Engine, fitted with 15 h.p. motor, and arranged with side drive: a Compressed Air Jigger Conveyor Engine, arranged with side drive: and a 6 ins. by 8 ins. short type Hauling Engine.

RICHARD SUTCLIFFE.

The exhibits of Messrs. Sutcliffe are to include: a Gate-End Loader: a Face Conveyor Driving Head: a Face Conveyor Tail End: and various sections of Conveyor Framework.

BRITISH JEFFERY-DIAMOND, Ltd.

A very considerable range of these well-known equipments includes the following:

An Electric Gate-End Loader, and the driving gear shown separately, together with two general purpose 60 amp. starting switches.

An Electric Blacket Conveyor, including troughs: a 15 h.p. Compressed Air Motor: a Jigging Conveyor Driving Gear, including Patent Rope Drive connections.

A 30 h.p. Electric Chain Coalcutter; a 40 h.p. compressed Air Overcut Chain Coalcutter; and a 13½ inch Compressed Air Jigging Conveyor Engine and Troughs: Electrical items include Circuit Breakers and a Gate-End Box.

HUGH WOOD & Co. Ltd.

An extensive range of coal face machinery and appliances includes the Eickhoff Shaker Conveyor; Electric and Air Haulages; Pneumatic Picks; Belt Conveyors; Steel Props, etc.

SULLIVAN MACHINERY COMPANY.

Principal items in the extensive display of Sullivan products are:—

A 12 in. Longwall Coalcutter suitable for 500 volt 50 cycle three-phase current, fitted with 4 ft. 6 ins. jib and the new nickel-molybdenum cutter chain.

A Scraper Haulage complete with 30 h.p. flame-proof electric motor and switchgear.

Two single Flame-proof Haulages, and two Compressed-air Haulages.

A Slushing Outfit consisting of a double drum air haulage on portable loading slide, together with a 36 in. box type scraper, roller bearing sheaves, etc.

GULLICK LIMITED.

An exhibit consisting of Electric and Air Coal and Stone Drills: Percussive Machines, Pneumatic Picks, etc.

CLIMAX ROCK DRILL Co. Ltd.

As compressed air specialists this firm will demonstrate examples of their well-known coalcutters, drills, picks and such accessories as dust traps, drill sharpeners, etc.

HARDYPICK, LIMITED.

The large range of Hardypick specialities is to be well represented. The examples shown include:—
Chain Coalcutter; the "Hardiax" Coalcutting Machine; Hammer Drills; Electrical Heading Machine; Air Hammer for sharpening Hand Picks; Air Compressors; Air Picks; Forging Machine; Wire Rope Cutting Machine.

MINING ENGINEERING Co. Ltd.

The principal items of this exhibit are to be shown in operation. The equipments include Electric Shaker Conveyors; Gate-End Loader; Belt Conveyor including Driving Head, Tension Drum, and equipment; Conveyor Head with air turbine; Air Engines, and a Gob Stowing Machine.

COWLISHAW, WALKER & Co.

Examples of this Company's products to be exhibited include two types of Longwall Coalcutters; an Electrically Driven Shaker Conveyor Driving Gear; and a Compressed Air Shaker Conveyor Driving Gear.

(*To be continued*).