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The "Qualifications" Report.

The Report to the Secretary for Mines of the Departmental Committee appointed to inquire into the Qualifications of Colliery Officials is now available as a Blue Book, costing two shillings. The deliberations and enquiries extended over a period of two years and it is highly creditable to the Committee that they have so quickly and so thoroughly explored a wide field beset with many conflicting interests and industrial difficulties. The terms of reference to the Committee required them to inquire into these matters relative to "the needs of the mining industry." Commendable also is the very definite, if not dogmatic, form in which the opinions and recommendations of the Committee are expressed in their Report.

The early pages are mainly devoted to a historical review of mining staff legislation, from its beginning in 1864 when the Miners' National Association petitioned Parliament to examine the scientific attainments of colliery officials and issue compulsory certificates of competency for colliery managers, agents, and overmen. It was only in 1872, after repeated pressure, that the principal of certification was legally adopted and enforced. Since then there have been several modifications introduced, these changes were principally in regard to the degrees of competency, first and second class; the extension of the range of knowledge required as covered by the examinations' syllabus and the age and experience of candidates; also the inclusion of other colliery workers whose duties, with the progress of mining methods, were becoming always more scientific and onerous. This present enquiry follows that sequence—that it was overdue is confirmed by the proceedings and findings of the Committee.

The mechanical and electrical developments in mining methods have outgrown the natural individual limitation of the normal man who as colliery manager cannot in these days truly be sufficiently expert in the detail of the scientific and skilled branches of work essential to modern mining. The safety of the mines, their economic stability and industrial progress demand of the engineer high degrees of qualification and competency which are in themselves sufficiently extensive and exacting to fill an intelligent man's capacity for training and practice.

Whenever the subject of Certificates for Mining Electrical and Power Engineers has been broached the obstacle of the manager's status immediately arose.

The Committee express the position very clearly: "The manager is by law responsible for the general control, management, and direction of the mine. This is the basic principle of the safety law, and it would be quite contrary to that principle that any official of the mine should be placed in a position of independence of the manager. But it seems to us that there is nothing inconsistent with the principle of general control by the manager in the assignment of clearly defined duties to other officials and in their being made directly amenable to the law for their proper performance."

So, in reference to the engineer-staff, the Committee have "thought it appropriate" to consider whether it would not be to the best interests of the industry and of the manager (in whom the responsibility for the safe working of plant ultimately rests and, by the Committee's ruling, shall continue to do so) that statutory qualifications should be prescribed for the engineer.

There are many forms of objection to increasing the range and number of compulsory certificates by examination. For instance, it was suggested to the Committee that State examinations should be used to promote other ends than those of safety. After mentioning that the present system, in providing guarantees of safety, necessarily calls for adequate technical competence, the Committee could not entertain the suggestion of the professional educational parties and re-

A. M. E. E.

21 YEARS OLD.

This Year The Association of Mining Electrical Engineers attains its Majority.

THE OCTOBER NUMBER OF THIS JOURNAL

will signify and commemorate, by historical record and report, the progressive development of the Association to its present state of sturdy maturity.

N.B.—The Editor will be pleased to receive any interesting notes or reminiscences concerning the early days of the A.M.E.E.

jected the proposition with the warning that to extend the certification principle beyond the safety-ensuring limit would tend to give to the Universities and the State the task of setting standards of education for industrial proficiency in mines. It would lead to scholastic restrictions of the field from which the right men for important mining posts can best be obtained and could not be "to the economic advantage of a productive industry striving for commercial results in an age of competition."

This commendable line of reasoning is more particularly applied to the consideration of examinations and tests for the manager's certificate; and naturally, it is consistently followed throughout the Report as other mining officials are dealt with. Thus, the Committee were unable to recommend the proposals of Professors and Organisers for Mining Education: the former would seek to give a new status to management and put the control of the suggested mining officials' certificates into the hands of a Committee composed mainly of professors and members of professional societies; the Organisers proposed that working miner students by attending part-time classes and passing examinations during a period of years would ultimately attain the Statutory Certificate. The hard straight comment on this vexed question reads "If there is a need in the Mining Industry, as there is in some others, for the establishment of professional or quasi-professional qualifications on an educational basis, it is not likely to be fully apparent from the special standpoint of either the Professors or the Organisers. The collaboration of industrial organisations, and of professional bodies, as well as of University Mining Departments and other centres of mining education, would be necessary for the success of such developments, and no steps in that direction have yet been taken. But if it proved possible to establish such qualifications by voluntary action within the industry, a new situation would have been brought about, and the question of transferring, in whole or in part, the existing responsibility of the State to a suitably constituted authority within the industry might reasonably be considered afresh."

It is very significant to note this curb to the modern tendency to give industry up to the experimental energies of the "educationist"; and pleasing to acknowledge the sensible line of action which the Committee indicates as the means of properly bringing education to aid the "needs of the mining industry." One of the five recommendations made in summarising the position regarding facilities for mining education further emphasises the necessity for putting education into the right perspective as the hand-maid, and not the nurse-maid, of the industry. It reads: "Organisers and full-time teachers of mining subjects should receive facilities for keeping in touch with changes in mining practice and arrangements should be made for securing the advisory assistance of men of high professional standing in local practice, especially in connection with advanced instruction in mining technology."

The concluding recommendations of the Committee in regard to mining electrical and mechanical engineers are:

"(1) That the Mines Department should lay down a code of statutory duties for colliery electricians and assistants to the electricians and for colliery mechanical engineers.

(2) That as soon as convenient, thereafter, the question of qualifications should be considered.

(3) That substantially similar provisions should be made for colliery mechanics."

These brief recommendations will not be so far-reaching as some of the electrical mining men (and their managers) had been hoping for: on the other hand they may reach too far to please others. The evidence leading up to these terse conclusions is voluminous and, naturally, highly controversial. We have only been able at this writing to touch lightly on one or two points but we shall doubtless deem it useful from time to time to make further comments. We strongly recommend readers to acquire the Report; they will be impressed with its teachings.

NEW BOOKS.

H.M. STATIONERY OFFICE.

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

Mines Department.—NINTH ANNUAL REPORT OF THE SECRETARY FOR MINES for the Year ended 31st December, 1929, and the ANNUAL REPORT OF H.M. CHIEF INSPECTOR OF MINES for the same period with statistical Appendix to both Reports. Price 3s. 6d. nett.

This report is divided into five parts. Part one deals with the general conditions of the Coal Mining Industry during 1929, referring more particularly to the wages and profits; legislation; and the miners' welfare fund. The second part concerns other mining and quarrying industries than coal. The third part deals with proceedings under the Working in Mines Acts; whilst part four reports in detail upon Health and Safety Work. The fifth section is the usual annual report of H.M. Chief Inspector of Mines, under the Coal Mines Act 1911.

Mines Department.—REPORT TO THE SECRETARY FOR MINES OF THE COMMITTEE appointed by him to inquire into the Qualifications and Recruitment of Officials of Mines under the Coal Mines Act. Price 2s. nett.

This book will be read with the greatest interest by mining electrical men, in that it is the complete report of the special committee, which for two years has been inquiring into the qualifications and status of Colliery Officials, including the Electrical and Mechanical Engineers of Mines.

Engineers engaged in these services have not by any means been agreed as to whether compulsory certification is necessary or desirable. This report clearly sets out the case for and against, as was put to the committee by representatives of the several branches of industrial and educational interests connected with mining.

The ultimate recommendations of the committee are that a code of statutory duties for colliery electrical and mechanical engineers should be established, and that the question of qualifications should be considered after the institution of the code of duties.

Proceedings of the Association of Mining Electrical Engineers.

WESTERN DISTRICT SUB-BRANCH.

Some Considerations Governing Power Costs at Collieries.

S. T. RICHARDS.

(*Paper read 11th January* 1930)

The recent depression in the coal mining industry has occasioned very minute investigations with reference to the production of coal at a price per ton comparable, if not cheaper, than that of other competitors. Among other very vital factors, the cost of power is an all important element, and a few considerations on this would not be amiss.

Power in collieries is generally used in one or more of the three forms—steam, compressed air, and electricity. There are other forms of power, but it is not intended here to discuss which form it should take. Each particular installation should be studied according to its own local conditions, and the method employed should be the one found most satisfactory to suit these particular conditions.

In his paper read before the Institution of Electrical Engineers in 1926 entitled "Electricity in Mines—A Short Survey," Mr. R. Nelson stated, in dealing with colliery generating plants and their justification, that the latter is due more or less to the fact that the mining engineer has usually the argument of a plant in being to support his view, coupled with the fact that he can utilise a fuel for which a sale cannot always or readily be found. On the other hand, to set against these substantial arguments, the mining engineer has very rarely a complete appreciation of the fact that his power plant, as such, regarded from the point of view of efficiency, is a very indifferent performer indeed. Further, continued Mr. Nelson, the mining engineer's method of keeping power costs may well leave something to be desired in respect of accuracy and completeness, and it is only where these accurate records are available that a true comparison of costs can be made. As a result of investigation at a particular colliery it often transpires that the prevailing idea of the cost per unit of current has its justification more firmly founded on tradition than on measurement. It is unusual for any records to be kept and it is only when proper records are kept and due provisions made that it is possible for any approach to a true comparison of costs to be derived. In the subsequent discussion on the paper Mr. Nelson was supported in his opinions by many of the leading engineers of the day; the present author admits also to an inclination to agree.

This paper submits for consideration a few facts, which the author believes should be laid bare when considering power costs, otherwise some very queer results are obtained, conclusions based on false premises may cause severe losses instead of the gain looked for.

Most collieries employ more or less the three forms of power enumerated above; steam being used on surface, compressed air and electricity for both surface and underground work. The fuel generally used is coal, the colliery product itself, hence economy in this direction is of the greatest importance, thereby releasing more of the saleable product for the market. When it is considered that many plants have in the past been consuming something like 12½ per cent. of their respective outputs, there is little wonder at statements such as that which averred that the waste of fuel at collieries would keep a few of the super stations going. A fantastic statement perhaps; but it has a certain truth in its meaning. It is, however, only fair to colliery engineers as a whole to credit them with having given the subject a very thorough and careful study: they have had to wrestle with problems, not met with elsewhere, in their endeavour to consume the most inferior and unsaleable coal existing in dumps around the collieries, and the results they have obtained are very satisfactory.

Having studied the steam producing methods and having obtained the steam as economically as is possible with the plant at disposal, leads on to the consideration of the factors governing or making up this cost.

In arriving at a true and accurate cost in any steam producing or power plant, the following items must be noted and included:—

(1) Labour Charges.
(2) Office Charges.
(3) Compensation and National Health Insurance.
(4) Stores and Materials.
(5) Oils and Greases.
(6) Repairs and Renewals.
(7) Water Charges.
(8) Coal Charges.
(9) Wagon Hire.
(10) Home Consumption or Power for Auxiliaries.
(11) Rates and Taxes.
(12) Interest and Depreciation.
(13) Insurances.
(14) Wayleaves.
(15) Easements.
(16) Any other incidental charges.

Against these charges must be offset any credits to the plant. In the foregoing it is assumed that no profits on the particular undertakings are to be made, i.e. all power charged out-balances the total cost of production as made by a sum total of the foregoing items.

On analysis it will be found that the foregoing items can be allocated into those costs which are variable charges, and those that are fixed charges. The following are a few explanatory notes:—

Variable Cost of Production Charges.

(1) *Labour*—This includes all and sundry employed in the production of power, including that for operation and supervision of the plant.

(2) *Office Charges*—Includes all clerical work etc. necessary for costing, and other work in connection with the undertaking.

(3) *Compensation and National Health Insurance*—This is self-explanatory, covering accidents to workmen, etc.

(4) *Stores and Materials*—All general small stores, etc. required.

(5) *Oils and Greases*—Includes all lubricants required.

(6) *Repairs and Renewals*—These are charges for any repairs carried out to existing plant, and for any renewals of plant or portions of plant. As this item is proportional to the use of the plant, i.e. to output, rather than to the magnitude of the load, these charges should be better taken as averaged over a year, though they have to go forward to the accounts for the periods in which they are incurred. If these charges are included for the particular week or period installed, a fair comparison from week to week is not obtained. Some authorities prefer to exclude this item from the returns as used for controlling station efficiency.

(7) *Water*—This includes the charge for water when bought, including its treatment where necessary if bought or unbought. As the charges for water consumed vary according to a graduated scale of charges based on quantities used, care has to be taken that the proper amount is allocated.

(8) *Coal Charges*—These include the charges for fuel consumed. This should be weighed carefully.

(9) *Wagon Hire*—Includes the hire charges on wagons used for coal or ash purposes.

Fixed Charges in Cost of Production.

(10) *Rates and Taxes*—These are generally high, and are superficially estimated.

(11) *Interest and Depreciation*—These are usually expressed as an annual rate per cent. on the capital employed in the undertaking. These can be split up as follows:—

(a) The rate of interest which a Company would require upon its capital, supposing the plant to be an independent undertaking selling its output.

(b) An amount per annum expressed as a percentage of the capital providing for the renewal of plant in a certain number of years.

These two items are very often expressed as an annual percentage of the capital employed.

(13) *Insurances*—This is another item that is superficially estimated, and provides for contingencies, such as fire, etc.

(14) *Wayleaves*—This explains itself, it is a charge which sometimes has to be divided.

(15) *Easements.*

The foregoing particulars are not very difficult to obtain for separate steam, compressed air or electric generating plants, but for collieries where all these forms of power are used, the correct allocation of the costs and charges for each and all, is absolutely necessary, otherwise confusion might arise.

The following combinations might arise:—

(1) Generating Plant on Isolated Collieries, part Steam and part Electricity.

(2) Compressed Air Plants on Isolated Collieries.

(3) Exhaust Steam combinations.

(4) Central Power Plants.

(5) Collieries supplied with Power from (4).

(6) Collieries supplied in bulk from Private Power Companies.

(7) Collieries supplied as (6), and operating in parallel with own generating station.

Considering each in turn:—

Case 1.—Generating Plant on Isolated Collieries, part Steam and part Electricity.

There are no doubt, many advantages in each colliery having its own local generating station; and, on the other hand, there are many disadvantages. This has been a very debatable point for a good many years, and now that low grade fuel, and coal that is more or less unsaleable, can be successfully and efficiently burnt, the lot of the isolated colliery has been improved, and some very excellent power costs obtained, in some cases figures which Power Companies could not compete with.

With one central boiler plant for the purpose of producing steam for steam plant and electric generating plant, the costs are not very difficult to obtain, provided the correct allocation of steam used for the different purposes is known. This naturally introduces the question of metering. For a correct allocation of costs, all feed water should be measured, and also the total water evaporated, the coal consumed should be weighed, the amount of steam to the colliery steam main measured, and also the steam to the generating plant. Having obtained all the particulars, each is then allocated to its particular apparatus.

Where various kinds of plant are installed for the generation of the different forms of power, the capital costs of these items should be determined and shewn separately, together with their proper proportion of the common unit. Take for instance the case cited of a station supplying steam, electricity and compressed air, with central steam boiler plant, all steam plant, electrical plant, and compressed air plant would bear their own capital charges together with their proportion of the capital charges of the central boiler plant, in the proportion of the amount of steam used for the respective units.

The total charges can then be allocated according to amount of steam used on each plant. This would then give a true cost of steam generation for colliery use, and a true cost of generation per unit of electricity. If metering apparatus is installed permanently, a true weekly or monthly cost can be obtained with a fair degree of accuracy.

Case 2.—Compressed Air Plants.

Again, where compressed air plants are installed, the metering of the air produced and consumed is a necessity and, in a similar manner to Case 1, the cost of compressing 1000 cu. ft. of free air per min. is found.

It might be argued that the installation of meters is a costly item. There is quite a deal of truth in this, but when new plants are being installed, the additional cost of metering apparatus is a small item compared with the capital cost of plant. The economies gained by the use of such apparatus, through the knowledge obtained of the operation of a plant and its results, provide a quick return on money spent. Waste of power is soon spotted, and immediate steps can be taken to remedy this. The metering of compressed air is as important as that of electricity. How many installations in collieries carry out an air balance, pump up, or leakage tests. The results obtained are astounding, and how else is the overall efficiency of a compressed air system to be checked and kept under observation? The old saying is "electricity shocks, steam burns, but compressed air is good for the ventilation of the mine." There are electrical engineers and mechanical engineers: why not compressed air engineers? Expensive plant, and highly efficient at that, is installed on the surface and operated under skilled supervision but, once underground, it is almost forgotten. A weekly cost sheet of compressed air consumption to every manager would soon open his eyes. In a fairly efficient reciprocating compressed air plant, the average cost of compressed air is 2½d. per 1000 cu. ft. of free air. Overall efficiencies of compressed air systems are generally very low. Again, the installation of inbye compressors is often prohibitively expensive.

Case 3.—Exhaust Steam Combinations.

These combinations are too well known to need enumeration here. Turbines can be used to great advantage for running on the exhaust steam from reciprocating engines, and extracting thereby a very considerable amount of the energy in the steam by expanding it down to the lowest practicable limit. In actual practice the output obtainable from the exhaust steam is usually about 75% of the output of the engine, though theoretically there is nearly as much work available on the low pressure range of steam as on the high pressure range. A very prevalent idea is that in plants working with exhaust steam no charge should be included for that steam; but the exhaust steam should be charged according to the available heat in that steam as compared with the available heat in the steam supplied to the reciprocating engine, before any true figure can be obtained for the cost per electrical unit and for the compressed air generated.

Case 4.—Central Power Plants.

Where collieries, or groups of collieries, are situated near one another, economies can be effected by the erection of one central station for the whole group. The capital cost per kilowatt installed is less than that of the individual colliery with its own plant. Less standby plant is required. Power station operating efficiency is higher, advantage being gained by the diversity factor of the individual colliery loads. By diversity factor is meant the ratio of the total of a number of separate maximum demands to the total or combined simultaneous maximum. Again, larger individual units can be employed at the collieries, and there is the advantage of ensuring continuity of power supplies.

With a plant of this sort, some collieries can be wholly electrified, enabling the older boiler plants to be shut down, so that standby losses are brought to a maximum. These are just a few of the advantages resulting in the unit of power being produced at a low cost.

Here again, the segregation of costs needs a thorough investigation on the lines previously indicated. (A metering chart was exhibited shewing a method of metering the various items, and also a specimen cost sheet of an installation in which power is produced for diverse purposes.)

Case 5.—Collieries fed from Stations, as in Case 4.

In regard to the question of costs, and apportioning them, this introduces the question of distribution costs to the individual collieries. To transmit power in compressed air entails the cost of transmission lines and pipe lines. To the generating cost at the central station must be added the distribution charges. Each colliery must bear its share of the distribution capital charges, transmission maintenance, labour, repair charges, wayleaves, etc., together with all losses, such as transformation, line losses, and, in the case of compressed air, pipe losses, etc. It will be found that the distribution charges form an appreciable portion of the nett charge to each colliery, demanding a careful study and supervision of the distribution of loads and their economical use in the collieries.

A good load factor in a distribution system is as important as a good load factor in a generating station.

Case 6.—Bulk Supplies.

Quite a good deal has been written with reference to this mode of supply so that only a few remarks are required. As is known to all, the charges for a "bulk supply" are usually made up as follows:

(1) Unit Charge, at so much per unit.
(2) Coal Clause.
(3) Maximum Demand Charge.
(4) Power Factor Rebate.

This is now a fairly standard method of charging. It has been mentioned in favour of bulk supply, that unless a colliery can generate its electricity at less than ½d. (half-penny) per unit, it would pay to adopt a bulk supply. There is still some truth in that statement, but the author's experience is that if power companies could deliver power at a half-penny per unit all-in charges, they would do the coal-field an immense service. The average cost generally works out at .8d. to 1.1d. per unit, and even higher . With reference to the basic charge per unit, it would be interesting to know, when these agreements are being made for bulk supplies, whether the classification and line incidence of the colliery loads are considered. For instance, the heaviest colliery loads are generally on an off peak period of the power load, therefore the standby charges per unit should be less for this type of load than for other loads.

For a colliery with a bulk supply the load conditions must be seriously considered, as otherwise excessive maximum demand charges result, and it behoves every colliery engineer to study the larger units under his control most carefully. It is essential that as uniform a load diagram as is possible be obtained in order to have the lowest costs. Again, this type of load has to be seriously considered and analysed. For instance one finds such loads as large ventilating fans and air compressors exceptionally expensive. In some cases one finds such results as the maximum demand charges being twice as much as the unit charges.

The coal clause is very often based on increased and decreased price of coal utilised at the station of the supply company; this should be charged as for a coal of agreed calorific value. Several grades of coal and at different prices are supplied to power stations during the period of agreement. It would be interesting to know how some of the figures for increase or decrease per unit for a corresponding increase or decrease in the value of coal used is arrived at.

The definition of maximum demand is: the maximum rate at which power is consumed over a certain period of time, either half-hour or an hour. It has now been agreed by the authorities that in future, this period of time will be one hour. Therefore, the maximum demand is not, as is very often supposed, the peak load, though the latter is one of the main contributors.

Again, it has been asked whether the classification of the colliery load has been considered in conjunction with other loads, as a Supply Company's distribution system. Colliery loads follow more or less a certain regularity; the effect of regularity of load on a station is obvious. The maximum demand charges are fixed either per k.w. or per k.v.a. per annum, dependent to a great extent on the estimated power of the proposed consumer.

This leads to the question of the power factors rebate clause. Of the correction of power factor sufficient has been written, which if studied carefully provides a mass of information on the subject. The author would only add one comment—that too much stress is being put on the installation of correction plant in improving the power factor, and not sufficient emphasis on the installation of the proper type, size and kind of plant for the service required. There are certain instances of collieries operating at 0.85 power factor, with a wholly inductive load.

There is just one other point re bulk supplies: which is, where a colliery keeps standby plant, for use in case of an interruption of supply, the charges on this standby plant should be considered.

Another important consideration is that of operating a few of the collieries off the one supply. This would give one charge instead of three or four separate maximum demand charges, advantage being taken of the diversity factor of the individual colliery loads.

Case 7.—Bulk Supplies working in conjunction with existing station.

This forms a most interesting combination, the costing of which, and the segregation of the items, is mostly a compounding of what has been aforementioned. In this case the apportionment of load is an all-important factor. It might be found most economical to allow the supply company to have some certain sections of load, or all light loads, and week-end loads, keeping the existing station plant running at as high a running plant factor as possible.

The main obstacle in an arrangement of this sort, is the arrangement of terms suitable to both parties. A fair basis would be an average flat rate per unit based on the generation costs at both stations, taking into consideration the periods of supply.

It would pay to allow the supply Company to have all high load factor loads, if a maximum demand clause is operative; or to have a reciprocal arrangement under which the collieries' plant would feed into the Supply Company's mains at periods of highest demand and *vice versa.* A fair charge for this would be an agreed figure based on the generating costs of both stations under the new conditions, less line losses and capital charges to the receiver. A sliding scale arrangement based on consumption, may be agreed upon for the basic price 'per unit. The author holds the opinion that considerable saving could be gained by both parties in a working arrangement of this sort.

In conclusion it must be borne in mind, that when comparing costs of any form of supply with another, that the amount of power per ton of coal raised, varies for different localities, due to geological conditions etc. All necessary items must be included, and all charges carefully analysed, both for generation and distribution, and when all consumptions are expressed in terms of boiler coal and as a percentage of total coal raised, no wrong comparisons are made, otherwise an admirable object defeats its own ends.

SOUTH WALES BRANCH.

Safety and Efficiency in Mines.*

Discussion.

Mr. R. H. MORGAN.—Mr. Hutchings' paper may be likened to a most desirable trinity. Firstly, the the author has had an excellent and varied experience such as is essential for the basis of a paper of this type. Secondly, he has the ability to interpret and describe clearly his findings. Finally, the author has the generosity to give his experience to his fellows, a quality of mind, unfortunately, all too uncommon with those who have knowledge of things practical. Mr. Hutchings must be assured that his labour is greatly appreciated, particularly by the young members. It is often said that experience can be purchased only in terms of time, then this paper may be described as having saved years for many of the members.

Mr. S. B. HASLAM (Communicated).—I am very sorry I shall not be able to be present at the meeting as I should have liked to have paid a tribute to Mr. Hutchings for his very able, interesting and valuable paper. Mr. Hutchings' tribute to *The Mining Electrical Engineer* is very well deserved and we cannot stress this point too much, as this publication alone more than justifies a subscription to the Association.

The paper deals fully with precautions to be taken in mines in order to obtain safety, and efficiency, and I would like to direct the particular attention of members to the fact that Mr. Hutchings, like all other efficient engineers, puts safety first.

To my reading, Mr. Hutchings' paper stresses the opinion that accidents are not due in any way to faulty manufacture. The frailty of the human element is always with us, no amount of careful training and efficiency on the part of the chief engineer can deal with the carelessness or negligence of those under him, but managements can take certain precautions; I suggest that one of these precautions is to recognise the good work being done by this Association, and to support it by making it obligatory that the electrical staff should be not only members but certificated members of the Association.

Dealing with individual items, I am fully in agreement with the author's remark on the subject of the earthed neutral. My sole reason for saying this is the difficulty of ensuring that insulation throughout is in a good condition. It is of course a fact that working with an earthed neutral does make discriminative protection rather more difficult, and the general protection of machines becomes more expensive, but in spite of that, I do agree with the author.

Mr. Hutchings is to be congratulated on the importance he gives to the subject of earth plates. It is not only a matter of getting ample surface in the plates but, what is of more importance, the plates should be placed in carefully chosen ground. Recent instruments which have been designed for testing the resistance of earth shew a most surprising variation, and I would suggest that if all colliery engineers were to test for this resistance they would come across some surprising results, and possibly appreciate more than they do now certain occurrences which have been difficult to explain.

Whilst I cannot agree with the author when he says that no earth plates should be used underground, I do agree that if earth plates are used underground there is a possibility of cables and gear being earthed through these earth plates, and the continuity of the metallic earthing system lost; but, provided that there is definite earth continuity throughout the whole system, I see no

* See *The Mining Electrical Engineer,* August, 1930, p. 55.

reason at all why the very excellent earths to be obtained underground are not to be made use of.

The author's remarks on switchgear bear definite evidence of valuable experience, and I would only refer to these by impressing on electrical engineers the vital importance of keeping conductors at earth potential until all the work in hand is finished. As the author says it is not sufficient to remove the residual charge by earthing the conductors momentarily.

The varying conditions of mining work do throw very considerable strain on cables, especially shaft cables underground cables and underground switchgear and, in a great many cases, gear and cables which were of ample capacity when installed become overloaded in time as the power demand increases.

The use of reactances is very helpful, and I agree that as far as possible reactances should be placed, not necessarily in each shaft cable, but at certain points of the distributing system where the short circuit value of a fault current is likely to reach a danger point as regards gear; but I would urge on electrical engineers that it is more vitally of importance to see that the rupturing capacities of such gear are sufficient to meet not only present requirements, but also possible future requirements.

With reference to the insulation of motor windings, I consider that some form of solid insulation of armatures and field coils is very necessary for underground work, and I would like to suggest that when ordering fresh plant, it might well be specified that after the ordinary standard insulation has been provided the job should be completed by the whole being impregnated with one of the synthetic resins or varnishes of which there are several perfectly satisfactory forms now available in this country.

Mr. J. F. SMITH.—Mr. Hutchings repeats a common statement when he says that nuts and bolts on coalcutter machines should be provided with spring washers to obviate the danger of these working loose. The speaker's experience is that spring washers are not adequate for this purpose on coalcutters as the vibration set up, especially when the machine is ageing, is abnormal, with the result that spring washers fail, very often by fracture. In modern motorcar practice, spring washers have been discarded for those sections where excessive vibration is likely. There are a number of other mechanical devices for preventing nuts working loose which are far more reliable and positive in their action than spring washers.

Mr. Smith doubted whether the distance between earth plates has any appreciable effect when applying the usual tests with two earth plates for soundness of earthing. The resistance of connections to such plates, and the contact of the plates with the surrounding material in which they are sunk is of far greater importance.

Mr. Hutchings evidently prefers to have the neutral point of generators earthed through a resistance. Mr. Smith said he preferred the solid earthing of the neutral point for the following reasons.

Should a fault to earth develop on the generator stator itself, it would be equivalent to short circuiting the faulty stator coils with resultant danger of excessive damage to the stator. To provide for this contingency, a relay to cut off the excitation is provided, the relay being actuated by the earth current in the neutral point connection. Such relays are usually only sensitive to about 15% of the maximum fault current, i.e., the current when the fault to earth is at the stator terminals. Thus only 85% of the windings of the stator are protected, the 15% windings starting from the neutral point being those without protection. When a resistance is introduced into the neutral point connection, it has the effect of reducing the amount of windings protected with the result that a fault to earth may occur on windings at considerable voltage without the relay operating.

With reference to the question of the location of switch handles on left or right hand sides of switch panels, the main point appears to be that the handles should be in such a position that they can be readily and firmly operated. It is desirable that the location of handles should be standard as a composite board, say of 550 volts mining type gear, with handles on left and right would be very confusing.

In concluding, Mr. Smith thanked Mr. Hutchings for his paper and endorsed the tribute paid to *The Mining Electrical Engineer* from which he could generally dig out useful information not available elsewhere.

Mr. B. J. BURKLE.—The author mentioned that one of the chief factors in the safety and efficiency of mines is adequate maintenance. As far as maintenance is concerned it naturally begins with the chief electrician, where it ends, goodness knows. It is obvious that the staff must be interested in their work before 100% efficiency can be obtained, and it follows that the chief electrician and the management should do all in their power to encourage the men working under them to be interested in their work.

With regard to tests to switches, earths, insulation, etc. these are essential, and frequently too; the records should be kept in the form of graphs, particularly if the graphs are made easily available to the ordinary members of the staff. The benefit to the electricians would be that they would be able to see very easily what class of apparatus in the different situations needed the most constant watching.

With regard to earth continuity testing, Mr. Burkle said he did not agree with the author's method. Mr. Hutchings suggested taking the test of individual joint boxes first, and the whole earth test afterwards. The process should be reversed and the joint box test made last so that the final test would be an indication of the condition of the apparatus as left by the tester.

As far as underground motors are concerned, some improvement in insulation is desirable. Personally, Mr. Burkle would like to see them all totally enclosed. The increase in size that this would entail could easily be accommodated, and the extra weight neutralised by the use of some type of light metal inspection covers.

With regard to earth plates, the author had suggested copper plates, but cast iron plates having ribs cast on them to increase their surface and give them better contact with the surrounding ground, would be more serviceable.

A point not included in the paper is mention of the method for taking cables far inbye. It is impossible to get a drum in any distance inside, and the cable has to be taken off the drum. It is the practice in some collieries to pull this cable in behind a journey. This entails single suspension. Now when the single suspension method is adopted for shaft cables the manufacturer is consulted, and requested to make the armouring suitable. Unfortunately the manufacturer is never consulted when cables are drawn far inbye behind a journey of trams.

Mr. Hutchings' suggestion of shaft signalling is good. Although in practice there has been very few accidents, the possibility is there. The single and double signals proposed by the author would, however, go far to prevent any accident occurring.

Mr. W. B. WOOLLEY expressed his pleasure in having heard the paper, and hoped as many of the members as possible would visit Oakdale Colliery on the 1st March and inspect the plant there.

Mr. S. J. LEWIS submitted the following question: A fault occurred in a cable and the switch tripped. On test with a 100 volt Megger the reading of 800,000 ohms was got. The supply of 3,000 volts was put on and the switch again tripped. 550 volts was then applied and the cable stood up to it. Another cable on test shewed a value of only 400,000 ohms with a 1000 volt Megger and it is still working on 3000 volts with this insulation test maintained. What principle would Mr. Hutchings adopt to make a test for this fault?

Mr. J. B. J. HIGHAM said his experience with spring washers was that under severe conditions of vibration and stress they were liable to fail completely. The washers split in two and fly from under the nuts leaving the nuts and bolts loose. Spring washers had been largely used in the motor industry, but were now practically dispensed with and some sounder locking device adopted. During the war, Mr. Higham's experience with aeroplane engines proved that many spring washers failed at points where heavy stress and vibration occurred; for example, at cylinder holding down studs and nuts. The damage resulting from a loose cylinder may easily be imagined. He would therefore avoid the use of spring washers in any electrical gear subjected to shock and vibration; coalcutters and the like, for instance.

Quite a lot of electrical gear is in use in which studs are driven into holes which go right through to the inside of the casing; that is bad practice. The stud hole should be blind; this may necessitate a little additional work in the pattern making and in some cases a slightly more intricate casting, but it prevents the possibility of entrance of gases or the emission of flame, which may cause disastrous damage.

Referring to the subject of earth plates, Mr. Higham said this still required a lot of research but, as Mr. Idris Jones had said, with the completely metal enclosed systems used to-day there was no absolute need for perfect contact between the surface earth plates and the soil. If the bonding is efficient the earth is of secondary importance. Mr. Higham said he was strongly in favour of local earth plates in the mine and placed as near as possible to the apparatus to be protected.

Mr. E. D. C. OWENS (Communicated).—One of the great obstacles to safety and efficiency in mines is due to what I may term the use of obsolete gear which, in general, may comply with the written word. do not meet the recommendation of His Majesty's Inspector. It is often found that the electrical engineer has very little to say in the replacement of existing gear to bring it up-to-date, or as to the suitability of new plant. The chief point in the routine of work is the getting of the coal and there is no provision made for sufficient time for inspection, repairs, etc.

Referring to H.M. Electrical Inspector's Report for 1928, we find that switchgear is one of the chief offenders in causing both fatal and non-fatal accidents, and I would like to ask Mr. Hutchings whether in his long experience, he thinks full advantage has been taken of the greatly improved designs in switchgear. The author refers in detail in particular to British Standard Specification 229/1929: is it his experience that existing gear which does not so comply is being replaced, and if not, why not?

The author refers to electrically operated coalcutters but as South Wales uses only approximately 2% of the total used in this country we can, I think, turn to more profitable sources for attention. In my opinion I further suggest that electrical coalcutters should not be used at the coal face, as they and their accessories are always a potential source of danger.

Regarding liquid controllers, the general complaint is that there is an excessive slip (over the normal slip of the motor) in the nature of 12% to 14%. Can the author give his experiences on this point, and say what overall slip he obtains.

Capt. T. E. RICHARDS (Communicated).—I read Mr. Hutchings' paper on Efficiency with much interest and he has succeeded in compiling sound advice in the supervision of electric plant at collieries. There are one or two points which might be noticed. I marvel at the surprise which he experienced in not finding with a 1000 volt Megger the fault when a break-down had occurred on a 3300 volt circuit: it seems rather on a par with testing a high pressure boiler with a pneumatic tyre gauge. I would suggest that the writer might try a more efficient means of testing cables etc. which would be to use an induction coil with an interrupter which steps the voltage up to anything from 20,000 volts or higher.

This method would have the further advantages of simply indicating the presence of a weakness without a destructive breaking down of the insulation on account of the exceedingly small current consumed. In fact it would in effect be a static discharge across the weakened spot.

Then as to shaft signals, Mr. Hutchings mentions that there is a possibility existing of an engineman mistaking the knocks. In the Sterling system, this is dealt with, and I would refer to the Sterling catalogue, where a solution of this difficulty is given. I am surprised that in face of the recent new readings of Section 48, C.M.A., and the warm controversy on that point, no reference is made to the important question of communication by signalling and telephoning and the efficient upkeep of the same. Surely this would have a serious effect on the efficient working of the mine from every aspect.

Mr. W. A. HUTCHINGS (in reply) said he was gratified to find so many entering into the discussion. Perhaps he had been rather too dogmatic in some of his statements, but he had certainly succeeded in bringing out a very wide discussion.

The question put by Mr. S. J. Lewis concerns high resistance faults in cables. He states that in one case a switch feeding a cable, that on test gave a reading of 800,000 ohms, would not remain closed; while in another case the switch feeding a cable, which tested at 400,000 ohms, remained closed. Mr. Lewis had omitted to state the lengths of the cables, or even the setting of the trips, but, assuming the conditions to be identical, Mr. Hutchings would suggest that the trouble in the case of the 800,000 ohm cable was concentrated in a very short length; whereas, in the other case, it would seem to be a case of general overall deterioration. The fault in the 800,000 ohm cable would most likely be quite easily found if the cable was tested in sections.

Mr. E. D. C. Owens has implied that there is much obsolete and inefficient apparatus in the Mines to-day. Such is, indeed, the case, and as Mr. Owens says one of the reasons is that the electrical engineer has in the past had but little voice in the matter of the replacement of existing gear. The status of the mining electrical engineer and the electrician is however, slowly but surely being improved by the work of this Association. The rate of progress in the replacement of existing obsolete gear is, perhaps, all too slow chiefly for economic reasons.

With regard to the use of electric coalcutters, these machines can be made the most useful tools in the colliery managers' outfit, but they would assuredly be dangerous weapons in the hands of careless or indifferent men.

When a liquid controller is used, a slip of 12% to 14% may be experienced, but if the controller is properly adjusted and the grading of the electrolyte is correct, then the slip is far more likely to be in the nature of 6% to 7%.

With regard to the suggestion of Mr. T. E. Richards that a secondary coil and an interrupter might be used for locating faults that a 1000 volt megger failed to find. It does seem to be a very valuable suggestion on first consideration, but it is questionable, however, whether such an apparatus would satisfy in every respect the requirements of the General Regulations. The idea might be taken up with advantage by the manufacturers.

With reference to shaft signals, it will probably interest Mr. Richards to know that there has been in use for a period of sixteen years, at the collieries with which he, Mr. Hutchings, is connected, the system referred to. This system obviates the necessity for altering the present code of "one" for "raise" and "one" for "stop". Mr. Hutchings said he could claim to be the originator of the stop signal as included in this system. The device can be added to any luminous or dial system of shaft signalling and gave every satisfaction.

Mr. Burkle's suggestion that the records of tests should be kept in the form of graphs is a very good one.

The question of whether cast iron earth plates are better than copper ones is a debatable point. Both have their advantages and disadvantages, it being remembered that the contact resistance of earth plates should be as low as possible.

When a cable has to be taken any distance inbye, every consideration has to be given to the various methods of installing it. Perhaps the one method that can be advocated with the greatest degree of confidence is to carry the cable in by manual labour, after uncoiling it off the drum. Another method would be to lash the cable to the tops of trams spaced every 10 or 20 yards, after first coupling the trams with lengths of rope or chain. Also, it is possible to obtain suitable drums mounted on trolleys that can be taken a considerable distance inbye.

In reply to Mr. Haslam, it is desirable to correct a misunderstanding that might be read into the paper. Local earth plates can be used with advantage in many cases, but all apparatus must be connected to the main earth plates, which are consequently of first and major importance

The Electrical Inspector's Reports from the year 1923 to 1927 state, out of 47 fatal accidents, 15 were due to bad earthing. The provision of a good connection to a mass of earth is of special importance in colliery in-installations, having regard to the necessity of avoiding danger of shock.

Mr. Higham and one or two other speakers seemed to have found in their experience that spring washers were very unsatisfactory under excessive vibration. Mr. Hutchings said he had suggested spring washers for two reasons:—they certainly made it more difficult for any unauthorised person to remove the nut without the aid of a spanner; and spring washers would stand up to a certain amount of vibration. Some other more efficient method might be desirable for such apparatus as coal cutters; it is no matter what form it takes, so long as it ensures that the nuts do not work loose. Mr. Hutchings was in entire agreement with Mr. Higham in the matter of putting studs into holes which go right through the casing, remarking that, furthermore, the practice had been condemned by H.M. Inspectors of Mines.

Several speakers, including Mr. Idris Jones and Mr. J. Smith did not agree with the opinion that the neutral point should be earthed through a reactance transformer and a limiting resistance: it was very pleasing to note that none condemned the principle of earthing the neutral point. It would appear from the discussion regarding the best method to adopt when earthing the neutral point, that this was one of the most debatable points in the field of electrical engineering. It was perhaps not usually necessary to insert a limiting resistance in the earth connection for low pressure and medium pressure systems. If no resistance be inserted, a fault on a 500 volt system, having a resistance of 10 ohms would cause a fault current of 29 amperes; if the system were at 6000 volts, then the fault current would be 348 amperes. The current necessary to operate core balance or other leakage protection devices was seldom greater than 20 amperes, so that for the higher voltage system the limiting resistance would seem advisable.

With regard to the reactance transformer method, it is to be noted that once installed the attention required is negligible, and any additions may be made to the generating plant without alteration to the earthing apparatus.

MIDLAND BRANCH.

Mr. R. Wilson presided at the meeting held in Nottingham on April 30th last. The following were elected to membership of the Branch: L. B. Shewring, 12 Newcastle Avenue, Worksop (Member) and J. Sales, 19 Seventh Avenue, Forest Town, Mansfield (Associate).

The election of Branch Officials for the Session 1930-1931 resulted as follows:—
Branch President; Mr. C. D. Wilkinson: Vice-Presidents; Messrs. G. P. Grice and J. G. B. Northcott: Treasurer; Mr. R. Kitchen: Secretary; Mr. E. R. Hudson: Branch Council; Messrs. D. W. Adams, H. Cowey, A. P. Drake, R. E. S. Edwards, H. Peach, E. E. Pidcock, F. Smith, W. Smith, R. Walker, and V. Wyness.

Mr. J. W. Wright opened a discussion on "The General Regulations as to the Installation and use of Electricity, with Explanatory Notes." Mines and Quarries Form No. 11, January 1930.

Mines and Quarries Form No. 11.

Discussion.

Mr. J. W. WRIGHT.—Certain alterations have been introduced in some of the explanatory notes in the 1930 Memorandum. In the notes on Reg. 120 the following statement appears: "There shall be a scale plan showing where electricity is in use in the mine for power or for lighting." This apparently means that in future electric light fittings must be shown on the plans.

An extract from the notes on Reg. 124a reads: "The minimum size for overhead lines in particular should be observed, viz., No. 10, S.W.G., for hard drawn copper. The use of small gauge wire for lighting circuits about the surface works at mines is dangerous." It has been the practice in the past to use small gauge wire for overhead lines to isolated lights about the surface works. This practice is now condemned as being dangerous, and must be discontinued.

An extract from the notes on Reg. 124c reads: "Although earthing the system is optional except in the case of a concentric system, it is preferable to earth the neutral point of a three-phase system in all cases." This is probably the first time there has been a printed official ruling regarding the earthing of the neutral point, although the regulations in the past have inclined towards earthing

In the notes on Reg. 125a the interesting statement is made that "A normal healthy man fully clothed has been killed by electric shock at a pressure of less than 60 volts alternating current between line and earth." Such an extreme case as this forcibly drives home the necessity for taking adequate precautions even at these low voltages.

Certain exceptions are made to the requirements of Reg. 125b as follows: "For some large motors such as those used for winding engines supplied with direct current at 500 volts or thereabouts, several conductors may be connected in parallel because a single conductor of the requisite size would be unweildy. In such cases practical requirements will usually be satisfied by providing an earthing conductor equal to 50% of one of the components of the multiple live conductor." A few years ago when installing the electric winders at Thorsby Colliery, the speaker believed that the Bolsover Colliery Company made an application for exemption from the 50% earth conductor conductivity rule. This is in a sense an echo of that incident and it is certainly a sensible view to take.

Reg. 126b reads: "Where energy is transformed, suitable provision shall be made to guard against danger by reason of the lower pressure apparatus becoming accidentally charged, above its normal pressure, by leakage from, or contact with, the higher pressure apparatus." Under the old memorandum, the safeguards included three methods, first, earthing the neutral point; second, a substantial metal barrier between the two windings; and third, the electrostatic device to earth the low pressure winding upon a rise of potential. Speaking personally, Mr. Wright said he never could understand how a substantial metal barrier could be introduced into a rapidly changing magnetic field without perceptibly decreasing the efficiency of the apparatus. In the new (1930) Memorandum this fact is pointed out, and this method of complying with the requirements of Reg. 126b is looked upon with disfavour. Cold water is also poured upon the use of the electrostatic device which, it will be generally agreed, is a less satisfactory method from the safety standpoint, than the metal barrier. Mr. Wright remembered an occasion when a fault occurred on an 11,000 volt to 500 volt transformer which was protected on the low pressure side by an electrostatic device. The device certainly operated, but two ammeter coils at a distant point in the low pressure system also went down to earth. It was interesting to note that those meters were both on the same phase, but this was not the phase to which the earthing device was connected. It provided a strong case for the use of an earthing device in each phase. Earthing the neutral point of the low pressure winding is now advocated in the 1930 Memorandum as being the simplest and most reliable method of satisfying this regulation.

Coupling the above with the notes on Reg. 124c one can visualise a time not far distant when it will be compulsory to earth the neutral point of the low pressure side on a transformer fed system.

In the notes on Reg. 128c relating to the automatic protection of circuits the Couse Rosebourn system of direct current feeder leakage protection is referred to. Compared with the flexibility of the a.c. core balance principle, the Couse Rosebourn system appears rather unweildy. On an earthed neutral three-phase system the core balance principle can be applied at any point, beginning, if desired, at the coal face machinery. With the Couse Rosebourn system one must start from the main switchboard and protect each outgoing feeder, with the result that if the system of protection is not further extended, a fault on any cable or apparatus will trip out the main feeder. For the interest of those not conversant with this system, the speaker might mention that the cost of an earthing panel for a 500 volt supply the largest feeder being of 500 amp. capacity, is about £90, and then extra cost of incorporating leakage trips in circuit breakers is about £12 to £14.

We are informed in the notes on Reg. 130a that there will shortly be a B.E.S.A. Specification directed to selecting the better types of trailing cables and eliminating the remainder. Every mining electrical man will be very interested in this specification when issued: it will deal with a problem which has been many times discussed at various A.M.E.E. meetings and always without any approach to a satisfactory conclusion being the result.

Some very interesting notes follow Reg. 131c. Reg. 66b now applies to electrical apparatus which must be examined for mechanical defects each week and the examination recorded in Mines and Quarries Form No. 44.

The following suggestions are also made as a guide to the frequency of electrical examinations and tests.

Examinations.

(a) A daily examination (1) of flame-proof enclosure of apparatus in use where firedamp is a hazard, and (2) of earthing contacts between plug and socket for portable apparatus, and (3) of trailing cables.

(b) A weekly examination (1) of the internal parts of switchgear that is frequently operated, and (2) of all fuses and other automatic safety contrivances that from their nature or accessibility, may have been interfered with.

(c) A quarterly examination of all items of plant not included in the preceding, including for example, observation of the air-gap of motors, condition of switchgear that is infrequently operated, bonding and attachment of cables, and the state of the oil in transformers.

Tests.

Insulation Tests.—

(d) A daily test if possible of the system as a whole.

(e) A weekly test of cable and apparatus in use at or near the coal face or in any place where it is subjected to especially rough usage.

(f) A quarterly test (1) of the cable system in section, and (2) of all motors and switchgear individually.

Earth Conductor Tests.—

(g) A weekly test of cables or apparatus subjected to especially rough usage as at the coal face.

(h) A quarterly test of all other parts of the system in sections.

To carry out these suggestions means a formidable task where any normal amount of portable apparatus is in use. Take quite a small installation of ten coal cutting machines, five conveyors, and five gate-end loaders: that is, a total of twenty portable machines.

These would necessitate, with spares, twenty-five trailing cables and probably thirty gate-end switches. The following daily examinations would be required: Twenty portable machines to be examined for flame-proof enclosure and earthing contacts; thirty gate-end switches to be similarly examined; and twenty-five trailing cable examinations, bringing the total daily examinations to no less than 75. Considering that some of these machines may be two or three miles apart the walking time alone would occupy a considerable number of hours daily. In addition to these daily examinations there are the weekly tests as follows: Insulation tests to be taken on twenty portable machines and twenty-five trailing cables; earth conductor tests on twenty-five trailing cables. This means the same ground must be covered as in the daily examinations, but the man must carry a Megger and an instrument to take the resistance of trailing cable earth conductors. The installation of switchgear incorporating leakage protection and earth circuit protection is not accepted as a conditional relief from the frequency of these tests.

In conclusion, Mr. Wright suggested that if alterations in the Regulations were printed in type easily discernible from the rest of the matter, it would greatly facilitate the task of finding exactly where alterations had been made.

Mr. R. WILSON complimented Mr. Wright on the very thorough manner in which he had gone over the ground. He must have spent a great deal of time on this new publication, otherwise he could not have discussed it in the detailed manner he had. He (Mr. Wilson) proposed to review very briefly some of the points Mr. Wright had raised. He did not quite agree with the remarks made about lighting fittings. He thought the regulations could, and should be interpreted to indicate lighting in a general way.

With regard to Regulation 124, it was the practice to fit isolated lights with 14's or 16's copper wire where, no doubt, No. 10 gauge should be used. Personally, Mr. Wilson could not see a great deal of objection to it.

Respecting Reg. 125b, and the size of the earth conductor on large machines, he thought that was taking a very sensible view of the situation. He quite agreed with the note respecting earth shields; they were not advised, and as Mr. Wright said, one could see many difficulties with transformers fitted with shields of that form.

With respect to No. 130a and remarks about B.E.S. standard for trailing cables, he thought the specification dealt with the size of conductors, thickness of di-electric, and pressure tests. He did not see how it was possible to have a specification for the design in detail.

Referring to No. 131, duties of electricians, it was desirable and would be very nice if all the suggested requirements could be met, but he doubted whether in the majority of cases it could be done. It resolved itself into a question of £ s. d., and as times were at present he did not think that part of the memorandum could be fully complied with.

Another clause Mr. Wright had touched upon was the M&Q form 44 which should be filled in by the electrician. He, personally, until about twelve months ago had held the opinion that that particular form was one for the mechanical department, and had always assumed that it should be entered in the log book M&Q 10, and regulation 66b has never been mentioned in the duties specified for the colliery electrician before.

There was one point which Mr. Wright had not raised and which was very interesting; that was Regulation 132v, and he would like to ask members what steps had been taken to comply with this requirement.

Mr. WILKINSON said that it was sometimes thought to be difficult to comply with the Rules, but in his opinion it would be much more difficult without the very helpful Memorandum. Even if the points raised in the latter entailed extra duties for the electricians, in the long run it would result in the plant being brought up to concert pitch.

The Memorandum was an exposition of good practice; the clear way in which the items were set out showed that no pains had been spared in its drawing up, and a plant which fully complied with it would challenge comparison with any power station or industrial plant.

Mr. Wilkinson touched upon several regulations and particularly on No. 131a, which dealt with the competence of persons appointed. He said that he thought that since an assertion of competency did not relieve the management from responsibility, this point should lead to better recognition of the certificate of the Association.

Mr. G. P. GRICE said the thing which struck him most was the amount of work the electrician would in future have before him in trying to carry out the new regulations.

Mr. T. W. FOINETTE said, as an outsider, it appeared to him the Memorandum was well worthy of study by all electricians, whether they were down a mine or not. The danger he thought was that the Inspectorate might treat the memorandum as though it was part of the Regulations. The number of tests required by the regulations was appalling, and if all were attempted it was possible they would be done so perfunctorily as to lose their value. He, personally, would rather give the electrician more scope and tell him that the question of safety was in his hands. If a man was competent why not let him have his head and make him generally responsible. He certainly thought that No. 131a, which insisted on the competency of the electrician could be used to give the Association a little higher status.

Mr. A. W. WILLIAMS said this discussion mainly concerned the colliery men. There were quite a few of the regulations which seemed to his mind to show other than general principles. He thought regulations of this kind should be confined to principles and should not dogmatise on certain points. For instance, No. 130 indicated that there is a standard plug specification; it may be an excellent plug, but his contention was that a regulation should not definitely indicate any particular design, but should lay down a specification that all manufacturers could comply with

Flexible cables were always a very debatable point; he thought they should be standardised but not the internal specification; he would standardise diameters and permit brains to improve the internal specifications; otherwise it would eliminate progress. With respect to 130a, re pliable armoured cable, he thought the recommendations made were treading on dangerous ground. Mr. Horsley was, Mr. Williams believed, in favour of earthing the neutral, and also in favour of leakage trips and D.W.A. cables for underground use; yet, at the most dangerous section of the mine, he now appeared to advocate the use of the pliable armoured cables so that it may be possible to fit trifurcating boxes to the portable plant instead of plugs and sockets.

If this change was intended to get a more secure earth between the cable and the portable plant, a test which Mr. Williams had taken upon this point some little time back might be of interest. The contact resistance was taken between the cable gland and the conveyor frame, and in other cases between the gland and the switch case, several different makes were tested the results in all cases being almost similar, but the test taken in the case of the plug and socket of modern design had a contact resistance 30% better than the trifurcating box.

Generally speaking, Mr. Williams thought it might be taken for granted that there were several designs of plugs and sockets which may be relied upon to be perfectly safe in operation, and further it was generally agreed that the chief danger was the type of cable feeding the portable plant, which called for more attention in construction. The chief danger was in the possibility of short circuits within the cable, and in that respect the pliable armour did not offer any solution. The modern type of trailing cable could offer security, since the latest practice of sheathing each power conductor with a metal covering, and placing this metal covering in contact with a bare copper earth conductor makes it quite impossible for a short circuit to be set up, either by accident or design: provided such cables are used in conjunction with earth leakage trips as recommended by Mr. Horsley. With cable leakage protection, this type of cable gives full protection against the risks of a short circuit.

Mr. H. MORRIS said he was interested to hear Mr. Williams' remarks on trailing cables, but he personally thought the memorandum referred to the new cable which was being used in connection with coal face conveyors, and provided with 7/22 spiral wire armouring. With regard to the question of single *versus* double wire armouring, he thought the notes in the memorandum were confined to coal face conveyors also.

Mr. PIDCOCK mentioned, regarding the question of earthing the neutral and installing leakage protection, that he had had experience of a system recently where this method was installed, and the breakdown had been reduced by 50%.

Mr. WILKINSON said that on systems with an insulated neutral, one usually found that a fault on one phase soon gave rise to a second fault on another phase. This was quite understandable because if one phase went to earth the potential between the other phases and earth was increased, so that weak spots went down under the increased pressure. Leakage protection in conjunction with an earthed neutral, was therefore an advantage since it isolated faults on their inception and thus saved further trouble.

Mr. WILLIAMS referred to Mr. Morris's remarks on Mr. Horsley's advocating single wire armouring as against D.W.A.

Mr. MORRIS in reply said that short circuiting would depend very largely on the dielectric between core and core. Did Mr. Williams refer to overloading? If the core were large enough to stand a reasonable overload then he thought the chance of a short circuit was very remote.

Mr. E. R. HUDSON considered that one of the chief points was how to comply with the regulations with the plant already installed at a colliery. With possibly three miles of roads there was such a lot of apparatus at substations that it would be quite impossible to make diagrams of any particular circuit clear on the proper scale plan.

Mr. WILKINSON said that a single line diagram might be used, in conjunction with the plan, to show the necessary details.

Mr. R. WILSON said he was not advocating that earth leakage protection was not necessary. He quite agreed with Mr. Wilkinson and Mr. Pidcock that it paid to instal earth leakage protection, but what he wished to suggest was that there were other ways of getting efficient earth protection without earthing the neutral. He had no doubt, as could be proved by reports from the Mines Dept., that it might be a source of danger.

Mr. H. MORRIS, referring to flexible armoured cable, said he did not think any trailing cable should be used with a sheathing of less than 0.025 as a minimum.

Mr. G. P. GRICE said the memorandum certainly gave every colliery electrician scope to exercise his own individuality. Tests were useless unless properly compiled and kept in such a form that one was able to refer immediately to the position of any apparatus. The whole efficiency of the system depended on the man in charge.

WARWICKSHIRE & SOUTH STAFFS. BRANCH.

The meeting of this Branch held in Cannock on March 27th last was given to a series of interesting discussions on matters of everyday importance to the mining electrician.

Mr. Tomkinson opened with a short paper describing the practice of using oil-immersed gear at the gate-end, and whilst no little adverse criticism ensued, his opinions were warmly supported.

The subject of Cables was raised in a paper read by Mr. English who championed the cause of paper insulated cables for most purposes, where frequent shifting would not become necessary. His statistics appeared to astound most of his critics, but he was resolute and convincing.

Mr. Brown followed by introducing a discussion upon reading Reg. 128d of the Coal Mines Act in an endeavour to ascertain if isolators were necessary adjuncts to star-delta starters. Opinions were somewhat varied, but the subject proved extremely popular and was freely discussed by most of the members.

Notes on Air *versus* Oil Break Gate-End Breakers.

F. E. TOMKINSON.

Oil Breakers.

The outstanding defect of the oil breaker is that the human element has to be depended upon to maintain the oil at the correct level. Low oil level decreases very considerably the breaking capacity. With a large head of oil the gas bubble is kept smaller and there are more opportunities for cooling the gas.

When a circuit is broken under oil, the arc causes more or less cracking of the oil and inflammable gases are produced. If the switch mechanism is defective, or the contacts are not properly made, the arc may be sustained for some time and enough oil may be vaporised to form an explosive mixture with the air in the case.

There is a limit to the number of times a circuit can be broken under oil, and any piece of switchgear which is used for breaking circuits frequently under oil must have the oil renewed periodically if accidents are to be avoided (probably no other piece of switchgear in common use is called upon to break a circuit more frequently than a gate-end breaker) and the contacts burn away more quickly under oil; thus with the frequent oil and contact renewals the replacement costs are heavier than with air-break circuit breakers; this feature too must also necessitate more inspections and, where an oil tank is to be lowered, inspection is more difficult and labour costs are more. Furthermore, where is there less room for the inspection of a switch than one usually gets at a gate-end circuit breaker?

If the oil level is low and the arc flame comes to the oil surface at a time when the enclosed air mixture is explosive, an internal explosion inevitably results. In recent tests with high voltage and a large amount of power, traces of acetylene have been claimed to be found and it has been thought that this gas can produce an explosion without the presence of air. This has, however, not yet been proved conclusively.

An oil-breaker cannot be sealed hermetically because there must be some means of allowing the gas generated to leak away and, if the passage provided is adequate, a pressure of the order of 60 lbs. per sq. in. may be expected on explosion. It is not difficult to make cases strong enough to withstand this pressure but, if this passage exists oil is liable to escape, and dirt and moisture to enter. In colliery work this passage or vent may easily be clogged up, due to the stickiness of the oil and dust etc., in the atmosphere, consequently the breaker is inadequately ventilated. It will be understood that this vent is provided not only for allowing gas to escape but to reduce the pressure of the explosion.

The tilting of an oil breaker is liable to have very detrimental results to the efficient working of the breaker and, considering the way in which gate-end breakers are usually housed—just a hole cut in the side and in ground which is always more or less on the move—it is hardly possible to avoid the tilting of a breaker and this tilting will be much worse in some seams than others.

An oil-immersed switch should have ample air space above the oil, generally something in the nature of 30% of the oil tank, and be suitably ventilated, but whether due to the request from collieries or the desire for portability, cheapness, etc., this space is too often insufficient.

Now, supposing an oil-immersed breaker be called upon to clear several faults in fairly rapid succession, a considerable quantity of gas is generated and the consequences might be very serious, since the mixture will not have time to diffuse or to get away from the case, this being due very frequently to defective ventilation. Thus the stage is set for an explosion in a semi-ventilated chamber designed for ample ventilation. This mixture will surely be fired by an arc or possibly by hot metal being thrown about.

Engineers at one of the largest collieries in the North have recently been carrying out some experiments with both air-break and oil-immersed gate-end breakers, and they have definitely come to the conclusion that air-breakers are preferable. They further express the opinion that these breakers will eventually become general practice. It is interesting to note that the same tendency is also taking place in Germany.

Air Breakers.

The air breaker does not depend upon the human element to quite the same extent as the oil breaker. The breaking capacity of an air breaker for the same overall dimensions is much less than of the oil breaker, consequently the air breaker is made of larger dimensions, which has the beneficial effect of affording better facilities for mounting plugs, cable boxes, link boxes etc., and, in addition, greater clearances inside the breaker with the consequent better facilities for connecting up.

An air breaker does not generate explosive gases when opened on load, but a flame is always present and, if an explosive mixture enters, it is certain to ignite, giving rise to internal pressures up to say 100 lbs. per square inch. An air breaker can be sealed, but no cast iron enclosure can exclude gases absolutely and permanently, because gas can diffuse through the pores of the iron. This, of course, is a very slow process and scarcely likely to occur in practice

The later designs of air breakers are provided with a flame-proof vent, consisting of a number of mild steel plates with distance pieces to allow gas to escape. The area of this vent is generally arranged so as to reduce the maximum pressure due to the most explosive mixture to something like 25 lbs. per sq. inch, thus it is unnecessary to adopt any extraordinary means to strengthen the case.

Recent tests by Professor Wheeler have proved that these vents are sufficient to cool the ignited gases and prevent ignition of a surrounding explosive mixture such as might be found in a colliery. In modern practice it is usual to employ sheet steel for these breakers, thus reducing the weight very considerably.

Air-break circuit breakers are not bound to be fixed perfectly level. They can be tilted almost at any angle and they are more easily transported over rough ground. They are generally of strong design and can be hauled along without risk of injury to parts. A case was reported some little time ago of an air-break gate-end breaker that was left upside down for some hours. It was merely put back in a normal position and no oil had escaped from the time lags. The breaker was put straight away into commission without any adjustments being necessary: this could scarcely be expected to happen with an oil-immersed breaker.

The replacement costs are very much lighter with air breakers than with oil-break circuit breakers. At the colliery where the writer is engaged there are probably three dozen air-break gate-end breakers in all; at the pit in which he is mostly interested there are fourteen, the first four were installed about Nov. 1924, they have been in use for coalcutter work ever since and the only replacement required as yet has been one sparking tip.

General Summary.

The choice is therefore, between an oil breaker which properly maintained is absolutely safe, but improperly maintained may be very dangerous and which must have some sort of vent: and an air breaker which must be larger for the same current breaking capacity, need not be vented and is generally less liable to suffer from defective maintenance.

The advantages of the air breaker may be summarised as follows:—

1. The human element is not so important.
2. Freedom from oil level troubles.
3. Tilting is not detrimental.
4. No oil gas is generated.
5. Oil-immersed breaker far more difficult to vent efficiently.
6. Air breaker being larger is easier to inspect.
7. Has greater clearances.
8. Is more accessible.
9. More facilities for mounting, boxes, plugs, etc.
10. Less liable to suffer from defective maintenance.

Discussion.

Mr. S. C. LLOYD agreed with Mr. Tomkinson that air-break control gear, especially for the coal face, was better than oil-immersed, as it has been proved in practice that the maintenance is less and it is far better from a portable point of view. With the air-break gear there are generally more clearances, and it is far more accessible than gear of the oil-immersed type. Where there is constant switching on and off with oil switches there is a considerable amount of burning under the oil and maintenance is therefore somewhat heavy.

With regard to oil switches, when used as circuit breakers on a high tension supply where the switching on and off is very infrequent and a high rupturing capacity is needed, there is no doubt that the oil switch for this condition is quite satisfactory.

High tension oil-immersed reversers for duties such as winders, are used extensively and these are specially designed to meet the heavy service conditions. Air-break high tension reversers are made, and quite a number are in use working very satisfactorily, the maintenance on these being practically negligible. The reason these are not used more is on account of the cost. A high tension oil-immersed reverser would cost somewhere in the neighbourhood of £85, whereas the high tension air-break reverser would cost between £200 and £300.

Mr. DIXON stated that he found that oil-immersed gear on the coal face was very satisfactory in service, but admitted that very careful maintenance was necessary. He also mentioned that the cases had special vents, but it has been found generally in practice that this type of vent which he mentioned tends to choke and is not as good as ordinary rough machined flange joints.

Mr. G. M. HARVEY.—The greatest drawback of oil-break gate-end switches is the uncertainty which must always exist as to the maintenance of a sufficient head of oil above the switch contacts; this is particularly so in view of the fact that the switch is frequently moved and may be dumped down at the road side without much regard for its inclination to the vertical. Those who remember the Hulton explosion will recall that an oil-immersed switch then came under suspicion, although the evidence was inconclusive as to the possibility of sparking above the oil level.

It would appear to be general experience that contacts under oil burn away more rapidly than contacts in air under similar duty: Mr. Harvey said he would be glad if any member could account for this.

Mr. L. C. GUNNELL.—A definite ruling on this subject is now required. Originally oil in circuit breakers was intended for cooling and quenching the arc. The whole subject boils down to efficient maintenance and inspection.

Paper Insulated *versus* other kinds of Cables.

J. R. ENGLISH.

In deciding on the best type of cable to be used for any particular purpose, one has to consider the special conditions of the case. In mining cables one of the chief things to be provided against is mechanical damage. This may happen in various ways: a cable may be subjected to considerable tensile stress, particularly on steep inclines where the cable tends to creep through its supports and ultimately become very tight; when in this condition a heavy fall of roof on top of the cable would add considerably to the strain and might cause rupture. This risk is usually provided for by armouring the cable with steel wire of ample section and suitably applied so as to withstand the strain.

Secondly, the cable may be liable to crushing, or squeezing, caused by falling roof or sides or by runaway tubs and such like. Crushing is one of the most frequent causes of trouble and should be provided for. The ideal cable to resist crushing is the steel tape armoured type, with shaped conductors, paper insulated and lead sheathed. Unfortunately the steel tape armouring has a comparatively high resistance, owing to being lapped on spirally, and consequently it does not come up to the Regulation Earth Conductor Standard of 50% conductivity. It has a further defect in not being able to stand much tensile strain. For these reasons steel tape armouring is not considered suitable for mine cables.

The next best cable to withstand crushing is the double wire armoured type, with shaped conductors, paper insulation and lead sheathed. This cable will stand a considerable amount of squeezing and has the advantage on tensile strength and ample electrical conductivity in the armouring.

Many people have objected to the use of paper lead sheathed cables because of the difficulty in making joints and tailing off at the ends. They seem to think that a satisfactory joint cannot be made without plumbing the lead sheath. The writer has been using paper insulated cables for many years and has never had any difficulty in making satisfactory joints without plumbing. With well designed joint boxes and stout brass clamps, correctly bored to suit the cable in hand, scores of joints have been made which have stood the test of many years' service without failure.

As proof of the efficiency of such joints the following example is of interest. In February, 1916, one of our shaft cables was damaged by a steel rail falling down the shaft. The shaft is 560 yards deep and the rail struck the cable end on, and pierced it through to the core at a point about 100 yards from the bottom, fortunately the metallic core was not seriously damaged so that it was only necessary to remove a portion of the armouring and lead sheath and repair the insulation; this was done, brass clamps and joint box were fitted in the usual way and the box filled up with compound. Water has been dripping over that joint continuously for fourteen years and it is quite sound yet.

Having disposed of the alleged difficulty of jointing we will consider some of the advantages of paper insulated, lead sheathed cables as compared with other types.

1st. They will stand comparatively high temperature.
2nd. Decentralisation is impossible.
3rd. Current carrying capacity is considerably higher.
4th. Smaller overall diameter.
5th. Lighter weight.
6th. Last, but not the least important, open sparking is very improbable at any time and practically impossible where good leakage protective devices are in use. On the other hand bitumen sheathed and vulcanised rubber cables have been known to flash through and in some cases have ignited the outer jute covering.

In the author's opinion the best type of cable for mine shafts, main roadways and any place where the cable is not required to be moved very frequently is a cable with shaped conductors, paper insulated, lead sheathed and double wire armoured. In some of the smaller sizes single wire armouring would be quite satisfactory.

For other places where frequent movement is necessary the author recommends tough rubber cables such as cab tyre sheath or "maconite" with single or double wire armouring for protection.

In these notes particular reference is made to shaped conductors because they lie together more compactly than round conductors with a broad surface of insulation between them, and the overall dimensions and weight of the cable is considerably reduced.

In looking into the details of this matter of cables the author was surprised to find what a marked difference there is in size and weight between vulcanised bitumen and paper insulated cables. By what we have read from time to time we have been lead to believe that bitumen cable was much lighter than other types and it has been recommended on these grounds. It was greatly surprising to find that the figures and facts are just the reverse. Twin bitumen cable is 28% larger and 55% heavier than twin paper cable with shaped conductors. Three-core bitumen cable is 15% larger and 23% heavier than three-core paper cable with shaped conductors. These percentages are the average for three sizes of cable, namely:—

19/.052" = .04 sq. ins. Twin and Three core.
37/.064" = .12 sq. ins. Twin and Three core.
37/.083" = .20 sq. ins. Twin and Three core.

they may therefore be accepted as a fair comparison.

Discussion.

Mr. S. C. LLOYD asked Mr. English if he had experienced any trouble with the creepage of moisture along the paper insulation before the cables were put into service; he was told that the ends of the cables were very carefully sealed while in stock, and the proper sealing was taken care of when installed. Mr. Lloyd also raised the question of making a satisfactory connection between the lead covering and the trifurcating box for the paper cables without a wiped joint, as he was of the opinion that clamping was only satisfactory when very carefully done, owing to the squeezing up of the lead. Mr. English had not had any trouble in this respect.

Mr. L. C. GUNNELL.—It is always advisable to make an analysis should the water be suspected or known to be of a deleterious nature, on the strength of which an opinion can be formed as to the type of cable sheath best suited to the conditions.

A chief point concerning the merits of bitumen and paper insulated cables is the relative carrying capacities under similar conditions. The safe maximum current carrying capacity of a cable having the cores insulated with bitumen is less than that of a cable having the cores insulated with impregnated paper and bitumen sheath. It is possible to work the latter to a much higher temperature without risk of decentralisation. It is not wise to work a bitumen insulated cable above a temperature of 100 degrees Fahrenheit; paper bitumen, 120 degrees Fehrenheit; and paper lead 150 degrees Fahrenheit.

Mr. F. W. MAYNARD said he was in full agreement with Mr. English in that the paper lead types were the best for main feeders and along main roads where falls of roof were not likely to occur; but he could not agree that this type of cable would stand more rough treatment; a rubber or "maconite" cable is more resilient, and the liability to shearing is greater with paper cables than with those of a rubber base. He also thought that Mr. English had been very fortunate with paper cables in not having the trouble of moisture creeping along the cable from a cracked sheath; a trouble not unknown even in a new cable.

Isolating Switches in conjunction with Star-Delta Starters.

G. M. BROWN.

The author is prompted to seek other views on this subject owing to the fact that he has frequently found that the user of a star-delta starter of the usual oil-immersed type with no-volt and overload protection, insists upon having a separate knife switch to isolate the starter, notwithstanding that the same user would cheerfully install a slipring motor control unit comprising starter and circuit breaker without any thought of a separate isolating switch. This attitude appears to be illogical, because the star-delta starter is simply a circuit breaker with an intermediate switch position, and is in itself adequate to cut off all pressure from the motor.

On turning for guidance to the Coal Mines Act we find Regulation 128d which reads:

"Every motor shall be controlled by 'switchgear' for starting and stopping, so arranged to cut off all pressure from the motor and from all 'apparatus' in connection therewith . . . ."

A further reference to Regulation 118 defines 'switchgear' as meaning switches, or fuses, conductors, and other *apparatus*.

Consequently, if we substitute 'apparatus' for 'switchgear' in Regulation 128d, it would read:

"Every motor shall be controlled by apparatus for starting and stopping, so arranged as to cut off all pressure from the motor and from all apparatus in connection therewith . . . ."

It is this somewhat ambiguous word 'apparatus' which appears to provide the stumbling block.

On taking a step further and consulting the memorandum, we are advised that:

"This Regulation simply requires the provision of a main switch for the purpose of isolating the motor and any controller, starting switch or fuses used in connection there with."

This gets us deeper into the mire, because it introduces the term 'starting switch' for which there appears to be no definition, but it may provide the explanation of the attitude of the users referred to in opening these remarks.

The author would make the submission that the circuit breaker which is incorporated in the control panel of a slipring motor—especially if the starter does not interrupt the rotor circuit—is just as much a starting switch as is the star-delta starter and, as the latter cuts off all pressure from the motor and as there is no further 'apparatus' in connection therewith, the spirit of the Regulation does *not* call for any further switch.

Discussion.

Mr. G. M. HARVEY said he would draw attention to the recently-issued re-print of Mines & Quarries Form 11, with revised Memorandum, and point out that, although a star-delta starter, with a definite "off" position, might be considered as combining the functions of starter and of the "switchgear" required by Regulation 128d, no work could be done on the starter until it had itself been isolated. He believed that the necessity for an isolator must be governed by the proximity of the switchgear controlling that circuit. If this switchgear were not within a reasonable distance, an isolator would be necessary, more from the point of view of convenience than of compliance with 128d. He had recently seen a very simple, drum-type isolating switch attached to and interlocked with an oil-immersed star-delta starter, and taking up no more space than a trifurcating box.

Mr. S. C. LLOYD.—It seemed clear from the discussion and the general views of the meeting that there is no definite rule in the Regulations to say that isolating switches must be installed, but Mr. Lloyd said he was of the opinion that isolating switches should be used on applications such as coalcutters, loaders and conveyors at the coal face, so as to make sure that the supply could be cut off not only from the motor but from the controller or gate-end switch. The reason they were not universally used was on account of cost, and he felt sure that if the price of the gear was the same with and without isolating switches that in every case isolating switches would be put in.

Mr. Gunnell had raised the question of star-delta starters being fitted with isolating switches fully interlocked with the starter itself; that type of starter has been supplied for some time of the flame-proof pattern.

The question of cutting out the overloads in starting had been mentioned, and Mr. Lloyd felt that there was no necessity for this as the starter is only in this position for so short a period that it does not give time for the motor to heat up to cause any trouble, and as long as the starter is fitted with a free handle in the "run" position there would be adequate protection against short circuits or sucessive overloads of the starter.

Mr. L. C. GUNNELL.—Rule 128d of the C.M.A. stipulates that every motor shall be controlled by switchgear for starting and stopping. It shall be so arranged as to cut off all pressure from the motor and all apparatus connected therewith. To comply with this a main switch is necessary to isolate the motor, controller, or other apparatus.

The star-delta starter is a totally different type from any other type of starter. It has its own features and is particularly designed for its particular class of work. It can be so arranged that it embodies all the automatic features necessary to protect the motor in the event of overloads, short circuit and interruption of supply. It is also designed with free handle device so that it is impossible to hold the switch in against overloads. It can also be arranged to embody some form of gradation device so as to prevent the switch being thrown over from start to run position too rapidly.

Makers maintain that a starter conforming to all these conditions need not have any other form of circuit breaker or any means of isolating, but that is a point better left to the mining electrical engineer as it is a matter of conditions and general arrangements as to how best he can apply apparatus to obtain best results; safe and efficient means should be available so that the engineers' staff can isolate any part of the system when necessary.

Respecting Rule 128d, there should be no ambiguity about its meaning, and personally, Mr. Gunnell did not consider that the rule calls for an isolating switch, on the other hand he considered an isolating switch most essential.

The star-delta starter is very much used in connection with auxiliary haulages which, incidentally, calls for very severe duty to the starter, very frequent stopping and starting being necessary, this causing excessive wear to contacts, which probably have to be attended to during coal drawing. This, without some means for isolating, would cause serious delays to other apparatus which happen to feed from the same source of supply: without some means of isolating it would be necessary to open the circuit further out-bye.

Another point is in regard to protection against fault when the starter is in the start position; at present no protection is afforded excepting only in the running position.

Mr. ROSEBLADE asked Mr. Gunnell if he considered the isolating switch should be interlocked with starter.

Mr. GUNNELL answered that it should certainly be so to prevent misuse.

Mr. F. W. MAYNARD said, without reverting to the C.M.A. at all, he firmly believed that isolating switches were necessary for safe maintenance and should be fitted wherever possible. Take, for example, the case of a long feeder on which there may be a number of secondary haulages; if it should be necessary to effect a slight repair, then, without isolaters it would be necessary to shut down the whole of the haulers; and, as a number of these repairs are commonly carried out during the actual drawing shift, then the delays would be serious for trivial repairs. The isolater should of course be interlocked with the starter, in such a way as to allow the safe handling of the starter. The isolater need never break current and could therefore be of a simple nature.

It is also an advantage to have an isolating switch in a long feeder underground, situated near to the face, so that in the event of having to do some repair on the live side of a starter, it is not necessary to travel some hundreds of yards to cut off the supply. For this purpose Mr. Maynard uses an air-break, flame and explosion proof gate-end breaker, and replaces the fuses with heavy links, this not being intended as an electrical protection but as a maintenance convenience, the handle being either locked against unauthorised interference, or removed and kept in the custody of a suitable person.

Mr. G. M. BROWN, as the close of the discussion, said it would seem that while it was agreed that the Regulations did not necessarily demand the use of an isolating switch, the opinion of those having practical experience was unanimously in favour of its use on the ground of convenience. He would therefore gracefully withdraw the suggestion that the isolating switch is not desirable.

NORTH WESTERN BRANCH.

A Resumé of the Determination and Effects of, and Protection against Short Circuit Currents.

B. E. JONES.

(*Paper read March 28th,* 1930.)

SYNOPSIS.

The following remarks pertain primarily to alternating current systems:

1. *General.*
   The re-arrangement of existing systems.
   Cause and effect of fault conditions.
2. *Alternators.*
   The effect of inherent reactance. Determination of short circuit values. Temperature rise and effect of short circuit. Determination and effect of reactors. Arrangement of reactors. Electromagnetic stress.
3. *Switchgear.*
   Necessity for suitable switchgear. Determination of short circuit value. Conditions affecting rupturing capacity. V.D.E. Tables, and B.E.S.A. Tables. Conditions affecting design.
4. *Feeders.*
   The effect of fault conditions. Heating and electromagnetic stress. Arrangement of Feeders to obtain maximum inherent impedance.
5. *Protective Arrangements.*
   Reference to protective systems. Circulating current protection. Biasing Transformers. The use of reactance.

The re-arrangement of existing supply systems necessitated by the increasing demand, introduced factors which hitherto did not require serious consideration. Large Base stations have been installed at a comparatively high capital cost, and consequently it is becoming more realised that expensive plant must be efficiently protected and continuity of supply guaranteed. Of the most common faults which occur on a supply system, those of short circuit (either between phases or phase neutral) predominate, and owing to the large amount of power which is generated, very high values of short circuit current may be developed. The system may be subjected to severe stresses, which are to a great extent dependent upon the value of the short circuit current, consequently it is essential to ensure this latter value be the permissible minimum, and that suitable gear be installed which can deal effectively with such conditions.

ALTERNATORS.

The earlier types of machines usually possessed very close inherent voltage regulation and consequently the armature reactance was but a small fraction of the field ampere turns. This condition was eventually disproved since the output of the machine is restricted, and the value of the short circuit k.v.a. is dependent upon the amount of reactance. Consequently the more modern alternators have been constructed with greater inherent reactance. Outstanding features which are obtained by the employment of reactance at the source are: (a) Does not interfere to the same extent with the losses. (b) Ensures the machine from being subjected to excessive forces. To illustrate this point consider the following comparative examples, e.g. Consider an alternator to the following particulars (with which the question is concerned):

1. Output = 10,000 k.v.a.
   Inherent reactance = 2% wl

Alternatively

2. Output = 10000. k.v.a.
   Inherent reactance = 10% wl

$$\text{Short Circuit k.v.a.} = \frac{\text{k.v.a. machine} \times 100}{\% \text{ wl}}$$

$$\therefore \text{(1) Sh. Cr. k.v.a.} = \frac{10{,}000 \times 100}{2} = 500{,}000$$

$$\text{(2) Sh. Cr. k.v.a.} = \frac{10{,}000 \times 100}{10} = 100{,}000$$

The above results are instantaneous maximum values and considered at normal frequencies. It is readily observed that the value of the short circuit kva- is considerably limited by use of reactance, but it cannot be excessively employed owing to the interference with the voltage regulation. When incorporated at the source reactance limits the disturbance created by a short circuit, but does not assist in maintaining the supply voltage. It is essential to employ a proper ratio of "Alternator reactance to busbar and feeder reactance. Since the use of busbar and feeder reactance is restricted, (owing to interference with the voltage regulation) the amount of machine reactance is also limited if the proper ratio is to be maintained. The problems which must be dealt with are: (a) magnitude of the instantaneous maximum value, (b) the period over which this value is sustained, and the consequent effect of both a and b. The following Table 1 shows the temperature rise/sec. with an abnormal current density (i.e. conditions created by a fault).

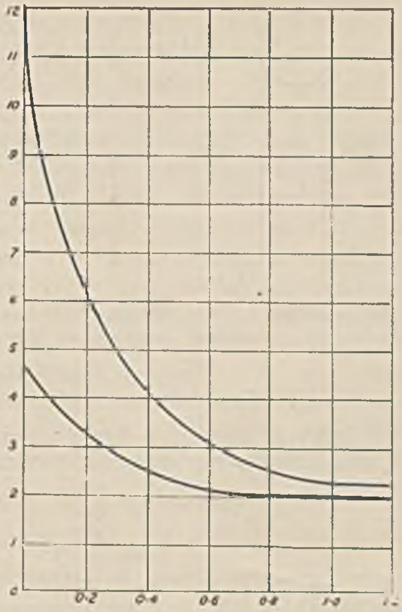

Fig. 1.

Current Density in Amps. per sq. in.		*Temperature Rise Degrees-cent. per sec.*
100,000	...	130
200,000	...	480

The above results are based on the conditions which would be existent in the feeders (e.g. underground cables). It is immediately apparent that a fault which is passing 200,000 amps. for a duration of one second, is far more dangerous than one which passes 100,000 amps. for a period of two seconds. (The foregoing time lags are arbitrary as the duration of a fault for the second period stated would not be entertained on the majority of systems in this country.

When a fault develops, the large current demagnetises the field, resulting in a consequent reduction of its values over a given period. Immediately the "short" occurs, the field is momentarily sustained by the eddy currents, and the value of the current is limited solely by the machine reactance. The reductions of the current values are illustrated by a reference to the curves in Fig. 1 showing the relation between Multiple of Sh. Cr. I. + N.F.L.I. and Time in seconds. The upper curve shows the effect of a "dead short" across the machine terminals and the lower curve the effect of a short through an external reactance.

The employment of direct parallel operation of multiple alternators further aggravates the trouble since the kva. which may be fed into a fault is considerably increased.

ALTERNATORS.

Machine No.		*Output k.v.a.*		*Inherent Reactance.*
1	... ...	10,000	... ...	10%
2	... ...	15,000	... ...	15%
3	... ...	20,000	... ...	10%
4	... ...	30,000	... ...	15%

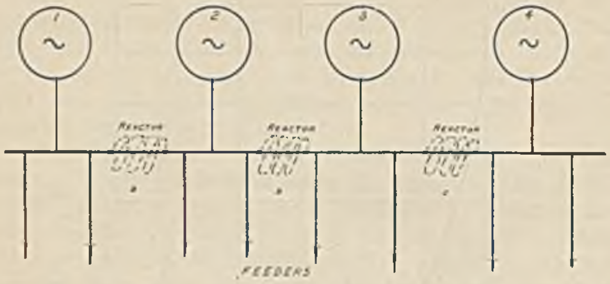

Fig. 2.—Simple Single Line arrangement of Multiple Parallel Alternators, showing position of the Reactors.

REACTORS.

Position.	Inherent Reactance—based on output of the nearest direct largest connected machine.
(a) ...	6%
(b) ...	6%
(c) ...	4%

For example consider a fault to occur on a feeder in the system shown in Fig. 2: *Case* 1, assume the busbars are "solidly" connected and not through the reactances. The kva. fed into the fault is determined as follows:—

(1) Consider an arbitrary base of 20,000 kva. The following table gives the % reactance at this selected base.

TABLE I.

Machine No.	% *wl*
1. ...	$\frac{20{,}000 \times 10\%}{10{,}000} = 20\%$
2. ...	$\frac{20{,}000 \times 15\%}{15{,}000} = 20\%$
3. ...	$\frac{20{,}000 \times 10\%}{20{,}000} = 10\%$
4. ...	$\frac{20{,}000 \times 15\%}{30{,}000} = 10\%$

Total combined reactance is

$$\frac{1}{\frac{1}{20} + \frac{1}{20} + \frac{2}{20} + \frac{2}{20}} = \frac{20}{6} = 3\tfrac{1}{3}\%$$

$\therefore$ Total k.v.a. fed into fault $= \frac{20{,}000 \times 100}{3.3}$

$= 600{,}000$ (Inst. Max.)

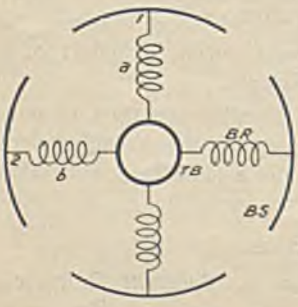

Fig. 3.—Arrangement of Busbars and Reactors in Star Design.

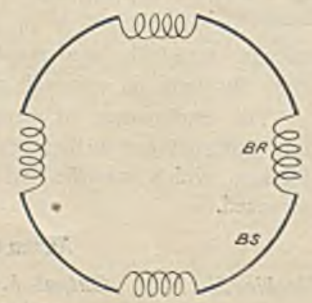

Fig 4.—Arrangmeent of Busbars and Reactors in Ring Design.

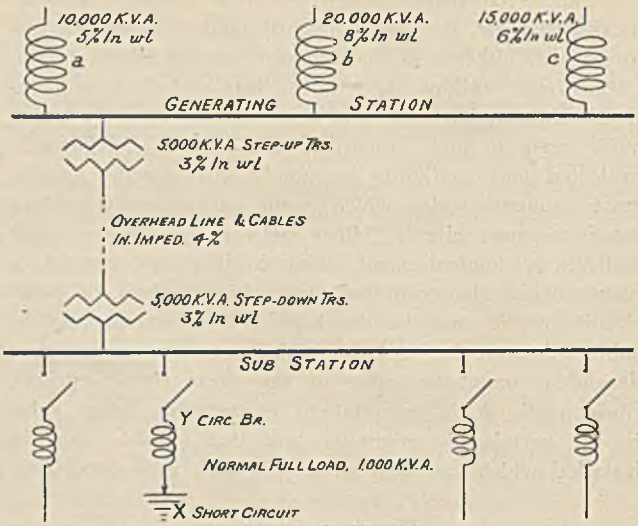

Fig. 5.—Simple diagram showing Fault Position, Sizes and Reactance values of Plant, and Impedance of Transmission System.

Case 2. Assume the busbars are sectionalised and inter-connected through the reactor. Then the k.v.a. fed into the fault is now determined as follows. The % wl of the machines at the selected base have already been determined in Table 1. The % wl of reactors to the above base are determined in the following Table 2.

TABLE II.

Reactor.	% *wl*
(a) ...	$\frac{20{,}000 \times 6}{15{,}000} = 8\%$
(b) ...	$\frac{20{,}000 \times 6}{20{,}000} = 6\%$
(c) ...	$\frac{20{,}000 \times 4}{30{,}000} = \frac{8}{3}\%$

The problem now presented is a series parallal one, and is closely analogous to a d.c. problem in which the resistance values are replaced by the % wl ratings.

Circuit Condition.	*Equiv. per cent. Combined Reactance.*	*Per cent. Circuit Reactance.*	*Result.*
Machine 4 and Reactor C are in series ...	$10 + \frac{8}{3}$ ...	$\frac{38}{3}\%$ ...	(E)
Machine 3 and result (E) are in parallel ...	$\frac{1}{\frac{1}{10} + \frac{3}{83}}$ ...	$\frac{830}{113}\%$ ...	(F)
Reactor B and result (F) are in series ...	$\frac{830}{113} + 6$ ...	$13\tfrac{1}{3}\%$ ...	(G)
Machine 2 and result (G) are in parallel ...	$\frac{1}{\frac{1}{20} + \frac{3}{40}}$ ...	8% ...	(H)
Reactor A and result (H) are in series ...	$8 + 8$ ...	16% ...	(I)

Machine 1 and result (I) are in parallel ...	$\dfrac{1}{\dfrac{1}{20}+\dfrac{1}{16}}$	... $\dfrac{160}{18}$%	... Final

Therefore the k.v.a. fed in to fault

$$= \frac{20{,}000 \times 100 \times 18}{160}$$

$$= 225{,}000 \text{ Inst. max. value.}$$

The use of "tie" reactors therefore limits the k.v.a. that can be fed into a fault. Consequently there has been a tendency towards the use of such reactors since they provide two distinct advantages: they assist in the synchronous operation of alternators, and they provide greater flexibility in the event of individual turbines possessing differing governing characteristics on varying load conditions. The arrangement in practice of the reactors, and machines per section may differ to that shown in Fig. 2, they are so placed in the figure for the sake of simplicity. The sectionalising and arrangement of the machines and reactors considerably affect the values of the short circuit current. There are several methods of busbar arrangements such as, single bus, simple duplicate, sub divided etc. The utilisation of busbar reactors however resolves itself into two common methods of design, viz., star and ring. Fig. 3 shows star arrangement and Fig. 4 shows ring arrangement.

The problem of load transfer (through the reactors) must be considered, the k.v.a. developed per section, and the number of sections, will influence the value of any (tie) or (external) reactors, and the consequent transference of load.

The electromagnetic stress or repulsion force, to which idividual conductors are subjected necessitates further precautionary measures against mechanical damage. Consequently unsupported (i.e. end windings etc.) are securely bound and fastened to ensure immunity from the foregoing trouble. In addition to the foregoing stress there is also that due to the heating of conductors (expansion) and when considering the case of busbars, suitable provision must be made to allow for this. The expansion may be absorbed by allowing the bar to deflect, i.e. taken up by slipping. A better arrangement however is obtained by the use of expansion joints, thereby ensuring sufficient mechanical strength to withstand the electromagnetic stress, and at the same time providing suitable means for the taking up of the expansion.

SWITCHGEAR.

This part of the system may be termed the most important link, as on it depends successful operation under fault conditions, since in addition to being subjected to severe mechanical stresses due to (a) repulsion (b) hydrostatic pressure developed due to vaporisation of oil by the arc energy (in oil switches), it must also be capable of interrupting a circuit whose arc k.v.a. is many times the normal continuous rating. To illustrate this point more clearly, mention may be made of a recent type of large circuit breaker which has a normal continuous rating of 600 amperes and an interrupting rating of 8,000 arc amperes at 220 k.v. or 3,000,000 arc k.v.a. The selection of a suitable unit should therefore be given careful consideration, keeping in mind the duty it may be called upon to perform. Due attention should be paid to the amount of short circuit k.v.a. that may be developed. It sometimes occurs that a controlling switch of the normal full load working is installed on a distant feeder, when it would be more advisable to install a switch of a slightly larger capacity. To illustrate this more clearly attention is drawn to the following example: Fig. 5 is a diagrammatic representation of a typical system in which for the sake of simplicity (since they would only be superfluous for the case under consideration) all intermediate, and auxiliary equipment has been omitted. The circuit breaker under consideration is denoted by the letter Y. Also consider the short circuit to occur across phases thereby enabling the currents to flow through circuits of defined reactance values. In the diagram Fig. 5:

In wl = Inherent reactance.
X = Position of short circuit which is assumed near circuit breaker Y.

Consider an arbitrary base of 20,000 k.v.a.

Equivalent % Machine Reactance.

Machine No.		% *wl*
(a)	...	$\dfrac{5 \times 20{,}000}{10{,}000} = 10\%$
(b)	...	$\dfrac{8 \times 20{,}000}{20{,}000} = 8\%$
(c)	...	$\dfrac{6 \times 20{,}000}{15{,}000} = 8\%$

Equivalent % Transformer and Feeder Reactance and Impedance.

			% *wl*
Transformer	(d)	...	$\dfrac{3 \times 20{,}000}{5{,}000} = 12\%$
Feeder	(e)	...	$\dfrac{4 \times 20{,}000}{5{,}000} = 16\%$
Transformer	(f)	...	$\dfrac{3 \times 20{,}000}{5{,}000} = 12\%$

The problem now presented is a series parallel one and is closely analogous to a d.c. problem in which the resistance values are replaced by the % wl ratings.

Circuit Condition.	*Equiv. per cent. Combined Reactance.*		*Per cent. Circuit Reactance.*	*Result.*
Machine (a) „ (b) „ (c) are in parallel...	$\dfrac{1}{\dfrac{8}{80}+\dfrac{10}{80}+\dfrac{10}{80}}$	...	$\dfrac{80}{28}$%	... 1
Transformer (d) Feeder (e) Transformer (f) are in series ...	$12 + 16 + 12$	...	40%	... 2
Result 1 „ 2 are in series ...	$\dfrac{80}{28} + 40$	...	43% approx.	...Final

Therefore k.v.a fed into fault at X

$$= \frac{20{,}000 \times 100}{43} = 46{,}500 \text{ Inst. max. k.v.a.}$$

From the diagram it is observed the full load of the system controlled by circuit breaker Y, is 1,000 k.v.a. Therefore the above value is 46 times in excess of the normal full load of system, and even assuming the circuit breaker is capable of interrupting a circuit many times the normal rating, it is hardly conceivable that it would be capable of "clearing" the above fault. If a slightly larger breaker was installed the fault would in all probability be "cleared' successfully.

The actual k.v.a. value obtained in practice may be be less, since on the occurrence of a fault the voltage is reduced and at the fault point, may be considered at or about zero potential. The reduction of the estimated value must not be overstated however because other effect may have to be dealt with, and in any case the introduction of a safety factor is automatically assured.

Development has tended towards the oil-break type of circuit breaker, but it would appear that if the same attention had been focussed on the air-break type a more satisfactory unit would have been evolved. Experiments have been carried out more recently on the utilisation of air-break type switchgear in larger units, and their adaptation as main feeder control gear.

Conditions which affect the rupturing capacity of oil-break switchgear.

1. Insulation.
2. Normal current carrying capacity limited to a temperature.
3. Speed of break.
4. Location and number of sparking contacts.
5. Length of break.
6. Head of oil.
7. Volume of oil.
8. Quality and viscosity of oil.
9. Clearances under oil and in air.
10. Volume of air above the oil.
11. Strength of tank and top chamber.

They should be mechanically and electrically trip free in any position of the closing stroke, thereby preventing pumping and the possibility of the breaker being held in against short circuit. On the break of the circuit the gases formed consist of

60 to 70% Hydrogen; 20% Acetylene; Remainder Methane and Ethylene.

the volume of the gases liberated during sparking being 45 c.c.'s per k.w. sec. of arc energy at 25° C., and at atmospheric pressure.

The Table III., composed by the V.D.E. (Germany), gives the leading dimensions of oil-break switchgear.

TABLE III.

Normal Pressure. volts.	*Short Circuit current in amps.*	*A ins.*	*B ins.*	*C ins.*
1500 ... 3000 ...	6000 3000	... 3	... 1 9/16	... 3 1/2
3000 ... 6000 ...	3000-6000 up to 1500	... 3 15/16	... 1 31/32	... 3 15/16
6000 ... 12,000 ...	3000-6000 up to 1500	... 4 15/16	... 2 3/8	... 4 3/4
12,000 ... 24,000 ...	1500-4500 up to 1000	... 7 1/16	... 3 1/2	... 7 1/16
24,000 ... 30,000 ...	1000-2000 up to 1000	... 9 7/16	... 4 3/4	... 9 7/16

Dimension "A" is the least distance in air between bare current carrying parts, and earth or between phases. Or if the apparatus is switched off between the various parts of the same pole or phase. Dimension "B" is the least clearance under oil to earth, to the surface of the oil, between phases. Or when the apparatus is switched off between the same pole or phase. This dimension applies only to oil switchgear.

Dimension "C" is the minimum depth under the surface of the oil to which the breaking point of an oil switch should be immersed.

The following tables are given in B.E.S.A. Specification No. 195 as standard ratings for a.c. generator and Feeder equipments.

Section 1.—Employing air-break circuit breaker or fusible cut-outs.

STANDARD RATINGS UP TO 660 VOLTS.

Equipments employing Air-break Circuit Breakers.		*Equipment employing Fusible Cut-outs.*
amps.		*amps.*
30	...	10
60	...	30
100	...	100
150	...	150
200	...	200
300	...	300
400	...	
500	...	

Section 1.—Employing oil-immersed circuit breakers.

Up to 600 *volts.*		*Above* 600 *and up to* 3300 *volts.*		*Above* 3300 *and up to* 6600 *volts.*		*Above* 6600 *and up to* 11000 *volts.*		*Above* 11000 *and up to* 33000 *volts.*
Amps.		*Amps.*		*Amps.*		*Amps.*		*Amps.*
60	...	60	...	60	...	60	...	60
100	...	100	...	100	...	100	...	100
150	...	150	...	150	...	150	...	150
200	...	200	...	200	...	200	...	200
300	...	300	...	300	...	300	...	300
400	...	400	...	400	...	400	...	400
600	...	600	...	600	...	600	...	600
800	...	800	...	800	...	800	...	800
1000	...	1000	...	1000	...	1000	...	
1200	...	1200	...	1200	...	1200	...	
1600	...	1600	...	1600	...		...	
2000	...	2000	...	2000	...		...	
3000	...	3000	...		...		...	
5000	...		...		...		...	
6000	...		...		...		...	

Since the rupturing capacity is dependent upon the design and manufacture, a few notes on the main requirements may be of interest.

The design resolves itself into the following main requirments.

1. The contacts and their arrangement, so that they will interrupt the circuit with the minimum liberation of energy at the point of separation.
2. Provision of a tank that will withstand the hydrostatic pressure due to the vaporisation of oil (due to the arc energy in oil circuit breakers).
3. Clearance allowances to prevent the possibility of flash-overs.
4. Sufficient mechanical strength embodied in such parts that may be subjected to "repulsion forces."
5. Should be "loose handle" or mechanically trip free in any position of the closing stroke.

The electromagnetic stress or "repulsion" force may under abnormal conditions attain serious proportions, the stress or "force" varies inversely as the distance, and proportioned to the square of the current, i.e. :—

$$F = \frac{K \times Ts^2}{k \times d}$$

With adjacent conductors (whose currents flow in opposite directions) spaced at (approximately) 12-14 inch centres the maximum repulsive force would be 12 lbs./ft. run, for a current of 15,000 amperes (r.m.s.). It is essential therefore to embody (a) sufficient mechanical strength and (b) clearance allowances, in the affected portions. The second feature (b) will under certain circumstances be influenced by the voltage.

The minimising of the dissipated energy during rupturing is obviously met by reducing the time taken to interrupt the circuit. That is, the duration of the arc must be minimised, provided that the rate of liberation of energy is not thereby increased during the arcing period. Reduction of the duration of the arc may be achieved in two distinct ways. (a) Forcibly increasing the resistance of the arc and thereby extinguishing it, i.e., by magnetic blowout, etc. These methods have been used extensively, but they possess an apparent disadvantage. Since by increasing the resistance of the arc they cause an increased rate of dissipation of the arc energy, and although the duration of the arc may be decreased, the total energy may remain undiminished or may be even greater than before. Also these methods are objectionable since by interrupting the circuit at an undetermined point in the current wave they may in certain circumstances cause serious electrical disturbances in the system. (b) The prevention from the arc restarting after the current has passed through the zero value of its cycle. This is achieved by leaving the arc alone during the passage of current but causing the resistance of the incandescent gases between the electrodes to increase suddenly at the zero of the current wave. A reference to Fig. 6 may explain this more clearly. In this diagram:

A.—Half current cycle.

D.—The point of the I cycle at which the breaker commences to interrupt.

B.—The part of the cycle during which the arc is left alone.

E.—Is approx. the zero value at which point the resistance of the incandescent gases are suddenly increased.

C.—Representing the sudden increase in resistance of the incandescent gases.

There may be a series of such resistance paths dependent upon the design of the breaker. To increase the resistance of the incandescent gases at the point of separation (these are highly conductive, being highly ionised) they may be de-ionised by one of the several known methods. These methods being enumerated as follows.

1. They may be forced into contact with a solid surface. This method being incorporated in the Slepion Deion Breaker.

2. The incandescent gases (which are, as previously stated highly ionised) may be removed altogether and replaced by cold non-ionised gases. This method being utilised in the air blast switch, and was incorporated some years ago in a standard type of air-break circuit breakers.

3. A cloud of solid particles may be injected into the arc, thereby deionising the gases by contact. This method would appear to be very effective but possesses the disadvantage of interference by the accumulation of solid matter.

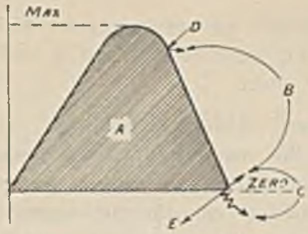

Fig. 6.

4. The incandescent gases and electrodes may be cooled as a whole by the media of a cooling liquid or forced gas blast. This being the principle of the ordinary circuit breaker.

It will be readily understood that the breaking speed of the ordinary oil circuit breaker is dependent upon the type and design adopted. This varies in practice from about 7 ft./sec. (including series breaks) for small oil circuit breakers at medium voltages up to 30 ft./sec. (including series breaks on some of the larger sizes and higher voltages. Referring to Table 1 under Section 1 (alternators) and the remarks following this particular Table, it is immediately apparent that switchgear with a high breaking speed is essential (within certain limits). The tank design is purely a mechanical matter, and an estimate of the pressure rise likely to be produced is obtained from experimental results and a tank provided accordingly. Allowance also must be made for the possibility of an explosion of the oil gases in the air space above the oil. The pressure developed by the ignition of explosive oil gases will depend upon the amount liberated and their constitution. The provision of pressure release device will obviously assist in ensuring a higher safety factor of the top chamber. Mention may be made of the possible abnormal voltage rise, which is liable to occur owing to the repeated formation and extinction of an arc, which would result in additional stressing of the dielectric. An outstanding feature from the user's point of view (which has been expressed by the Editor of the *Electrical Times* during his recent visit to America), has been the necessity for the user in certain cases to purchase switchgear of a higher voltage rating than that of the system, owing to repeated flash-overs when using switchgear the voltage of which is rated to that of the system. Under certain conditions where sufficient combined protection is embodied, feeders and transformers are connected "solidly" thereby eliminating switchgear. The latter, in the opinion of some engineers, is becoming very costly.

FEEDERS.

Dealing firstly with the effects of short circuit currents we may confine the considerations to two classes:

1. Overhead lines, (i.e. bare conductors spaced some distance apart).

2. Cables, (either in free air or underground).

The inclusion of cables (in free air) under section 2 is based on the assumption that since the conditions created are instantaneous, or alternatively are sustained over a comparatively short interval of time the effects (in general) are in both cases somewhat the same. Since the effects of short circuit currents (i.e. abnormal currents) are (a) overheating of the conductor; (b) creation of electromagnetic stress between individual conductors, we are concerned with their application to the foregoing classes 1 and 2, and the ultimate (or penultimate) effect.

1. *Overhead Lines.* Although condition (a) must affect overhead lines, the magnitude of the temperature rise must be less than that of cables of the same cross section on the same system (in the immediate vicinity). Also the electromagnetic stress (b) must be less since the spacing of the conductors is considerably greater than those of cables. Therefore, the dangers (a) and (b) which are created by short circuit conditions are exhibited more in cables than in overhead lines, and the following remarks pertain primarily to this class. 2. *Cables.* The heating of a conductor is dependent upon the value of the current, and the time for which this value is sustained. A certain amount of the heat generated by the conductor is absorbed by the surrounding materials resulting in a heating up of the cable as a whole, and if the value of the current is large enough the resultant effects may be disastrous. Accepting the opinion of some of the well known cable experts on the creation of voids due to heating, we may consider the effect of short circuit or fault conditions and their influence in this respect. Referring to Table 1, under Section 1, (Alternators) it is readily observed the effect of an abnormal current density (i.e. fault conditions), is the creation of an excessive temperature rise (if the fault is sustained for any length of time). Applying the present case to the aforementioned theory, there is under fault conditions a tendency to the creation of voids which in the case of high voltage cables would lead to ionisation and ultimate breakdown of the cable. The creation of voids due to heating may be attributed to three causes: 1. The differing co-efficient of expansion of the materials. 2. The difference in the volumetric quantity of the materials. 3. The distribution of the generated heat.

There is also the effect of linear expansion to be considered, but there is usually sufficient freedom and flexibility in the cable run which automatically provides for this. If the fault was sustained, fusion of the conductor at some point within its length would occur. A further contributory factor towards cable failures may be that due to the "electromagnetic stress," this value being proportional to the current squared and inversly proportional to the distance apart of the conductors. In a three-phase cable (under certain conditions) when carrying 10,000 amps. the maximum stress or force may reach a value of 10,000 lbs. per foot run, and may approach this value in or about the joint boxes.

The "repulsion force" may therefore approach a value such that the cores of the cable or sheath become distended, with the consequent creation of voids. The value of the factors (which may vary considerably) involved, however, decide whether the conditions created will result in cable failure. For instance the value of the short circuit current is controlled by the nature of the fault, the amount of reactance, and local conditions. There is then the question of the mechanical strength of the cores, the surrounding material and the lead sheath. Therefore, several reasons may be constructed which may contribute towards cable failure (due to ionisation).

Although under certain conditions if the hoop strength of the lead sheath be sufficiently high, the mechanical strength intermediatory to the conductor and sheath may not be beyond reproach. If the latter value is low a correspondingly reduced value of short circuit current, may be sufficient to cause core distention and ionisation. The foregoing remarks apply chiefly to E.H.T. cables, and since the values of the short circuit current are appreciably lower than those of H.T. or L.T. cable carrying the same amount of power, and the distance between cores is greater, the question of immediate rupture due to mechanical repulsion is not as serious.

A point therefore may be approached where a L.T. or H.T. cable (when connected to a source where a large amount of power may be fed through under fault conditions) may have an immediate failure. The failure may be due to two contributory factors. 1. Electromagnetic repulsion. 2. Heat generated (due to excessive current and the creation of a fault at the "blow-out"). A further danger that may be exhibited under fault conditions, is that of a voltage rise above normal which would result in an additional stressing of the dielectric, this factor would not be as important in L.T. cables as in H.T. cables. The value of the voltage rise would depend upon the inductance, and the part of the current wave at which the circuit is interrupted. This latter would point to the necessity for efficient switchgear.

Two points therefore which require consideration are: (a) The mechanical strength of the cable (i.e. considering each individual section) and (b) The potential grading of the insulation. Considerable attention has been focussed on condition (b) (this is exhibited by the varying types and methods adopted of E.H.T. cables at the present time). It would appear however that the same attention has not been focussed on condition (a) (beyond providing a sufficient mechanical strength for external reasons). Taking the case of a three-phase system, the adoption of three single core cables in lieu of a three core cable would appear to offer advantages.

There are, however, several other contributory factors other than those created by short circuit conditions which may cause cable failure. The inherent impedance of the cable itself assists in the limitation of the short circuit current, the equivalent per cent. impedance of a comparatively small size of cable being fairly appreciable at a selected plant base. The inherent impedance of the cable may therefore be taken advantage of, and the arrangement and grouping of a number of feeders (to obtain maximum protection) requires further consideration. Fig. 6 shows six station feeders arranged in two groups of three, to feed two substations with twelve outgoing feeders, i.e., six per substation.

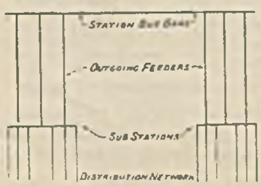

Fig. 7.—Simple single line arrangement of distribution system.

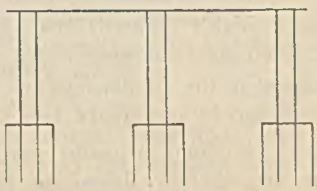

Fig. 8.—Simple single line arrangement of distribution system.

The arrangement shewn in Fig 7 may be regarded as giving a low inherent feeder impedance. Fig. 8 shews the same 6 feeders arranged in three groups of 2, feeding three substations each with 4 outgoing feeders.

It is immediately apparent that a far greater impedance is obtained by the second arrangement, and it also possesses distinct advantages. The advantages may be briefly enumerated as follows. 1.—Reduces the area or distribution system affected by a fault. 2.—This arrangement introduces more reactance near the source, and also near to the part to be protected (ensuring a reduced value of fault current). Also if the total copper section of the feeder cables are the same in Case 2 as in Case 1 the losses are not thereby increased and therefore regulation is not affected.

By suitably grouping feeders, maximum inherent impedance may be obtained, which may be sufficient to exclude the use of reactors (the employment of artificial reactance) and possesses the great advantages over this latter method that the voltage regulation may not be effected to the same extent. The impedance value is utilised when considering cables and not reactance only, since the resistance may be appreciable and therefore must be taken into account. Since the majority of systems have the neutral point earthed, the greater number of cable faults will first appear as earth faults, with a consequent reduction in the value of the short circuit currents. Also if the fault develops gradually, the earth leakage device will trip the faulty circuit before an excessive value is attained.

PROTECTIVE ARRANGEMENTS.

To ensure continuity of supply, and the efficient protection of the system, the protective gear must be (a) positive and certain in operation, (b) as quick as possible, i.e., the time lag between the occurrence of the fault and the tripping of the faulty portion being a minimum. (c) Discriminating, i.e., the faulty section *only*, should be isolated and not feeders which are themselves healthy but momentarily carrying the fault current. The two chief reasons for earthing the neutral of a system are (a) The limitation of voltages under fault conditions and for insulation purposes. (b) The assistance it gives to discriminating protective gear. A common method is to earth through a limiting resistance, which means that the earth leakage protection must operate at a value less than the limited current. Fig. 9 shews a common form of earthing arrangement. In Fig. 9:

A.—Single Pole Isolator.
B.—Single Pole, Oil Insulated, Circuit Breaker.
C.—Make-before-break Switch (optional).
D.—Earthing Resister.
E.—Current Transformer for Earthing Device (optional).

The best practice is to earth the largest machine, since this (earthed) machine takes the biggest shock on fault. The size of the earthing resistance is limited by the amount of protection required in the alternator winding, and by the value of the fault current it must carry in the event of an earth fault from phase to earth. Whether the neutral point should be earthed through a resistance or "solidly", provides a very controversial subject. Since on E.H.T. systems if the neutral be earthed through a resistange and a fault develops on

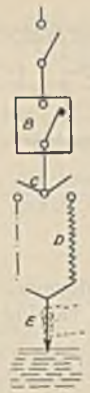

Fig. 9.

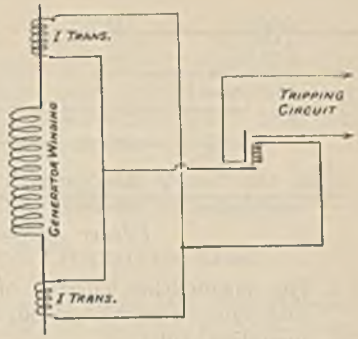

Fig. 10.—*Circulating current protection applied to generator protection.*

say, phase "A" to earth, a voltage may be maintained by the resistance and may result in an increased voltage between the healthy phases "B" and "C", resulting in an additional stressing of the dielectric. It is the usual practice in this country to earth the neutral point, although on the continent the use of insulated systems are universal. This latter method has not given satisfactory service in the past, but it has been improved considerably by the use of arc suppression coils (Peterson coils consisting of an iron cored inductance with a tapping switch).

Protective systems are so numerous that it is impossible to mention them all, therefore several are omitted, and others briefly dealt with. A recent paper (read before the I.E.E. and dealing with protective gear) forms an excellent treatise on this particular subject on present day practice and future tendencies. It cannot be too highly stressed that maximum protection is desired with the minimum number of components and satisfaction would be secured if when considering protective schemes, the services of the manufacturers concerned were secured. An interesting method of transformer protection is obtained by the use of the Buchholz relay, which is situate in the pipe between the oil conservator and the transformer tank. A fault is detected in its incipient stages, since the velocity of the gases generated is utilised to displace a float and close the auxiliary relay contacts.

A common method of protection of a.c. generators and transformers is the circulating current, this being briefly dealt with in the following remarks. The circulating current is undoubtedly one of the most simple methods of protection, and Fig. 10 shews a simple diagrammatic arrangement of such protection applied to an a.c. generator.

To obtain restraint when a fault occurs on another part of the system, it is unusual to set the relays at values lower than 20% to 25% of the full load rating of the current transformers, since there is the difficulty of manufacturing transformers to give similar secondary currents when the primary (owing to short circuit conditions) is carrying enormous currents. Sometimes other schemes have to be devised where it is desired to have a low relay setting. Although circulating current protection is applicable to transformer protection it is not under the same ideal conditions as when protecting generators. The main three contributory factors which reduce the effectiveness of circulating current protection when applied to transformers are:—

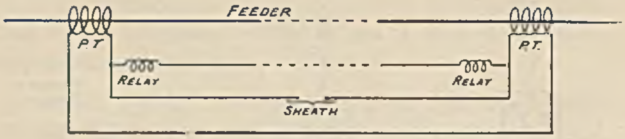

Fig. 11.—Simple diagrammatic arrangement of the application of Sheathed Pilot Cable to Single Feeder Protection.

1. The magnetising current of the transformer itself may cause a permanent out of balance, varying with operating volts.
2. The out of balance due to magnetising current when switching in may be very large.
3. The protective transformers on the primary and secondary side having different ratios, their magnetisation curves may differ considerably.

These difficulties may be overcome by the application of bias on the relay, which provides overload restraint and auxiliary restraint against abnormal magnetising current. Circulating current protection cannot be applied to long feeders, and a system employing opposed voltage may be utilised. The latter system is not so satisfactory as the former, for two main reasons, viz.:

1. It is difficult to obtain two identical transformers.
2. Since it applies voltage to the pilots it causes the flow of capacity currents which may operate the relay. The latter condition may be overcome by utilising a pilot cable with each core sheathed with a copper tape and left open circuit as shewn.

Capacity currents still exist but they do not flow through the relays, also bias can be applied to prevent tripping on through faults owing to unbalance of the protection transformers. Where pilot cables are available the above method may be applied to both single feeder and parallel feeder protection, but in the absence of such cables, reasonably satisfactory protection may be obtained by balanced current or balanced power protection for parallel feeders, i.e. assuming each feeder carries a definite proportion of the load. This type of gear discriminates between earth and line fault. A limited amount of load may be teed off a feeder without upsetting to any large extent satisfactory operation of the protection, the receiving end, however, must have balanced power protection unless there is a source of supply for fault current at that end.

Originally the idea of the designer was to provide relays which would operate with the minimum fault current, but it has since been realised that the difficulty is to prevent healthy feeders from becoming isolated in the event of a through fault which would result in the feeder having to carry momentarily a large fault current. As previously stated it is difficult to obtain

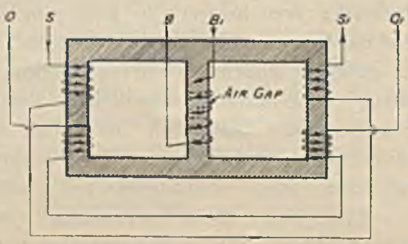

Fig. 12.—Schematic arrangement of Biasing Transformer.

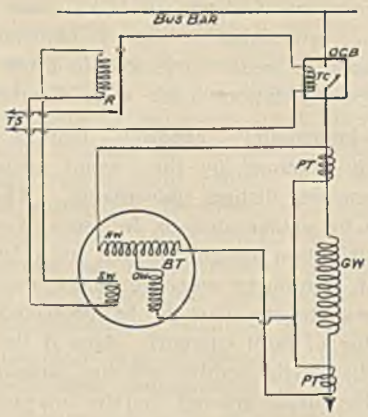

Fig. 13.—Diagrammatic arrangement of the application of Bias to Circulating Current Protection.

balance on current transformers with heavy primary currents and the application of a bias (either by relays or transformers to increase the settings on heavy through faults) has been utilised.

The outstanding features which are derived by the use of biasing transformers are:

(a) Overload restraint.
(b) Discriminating restraint.
(c) Directional operation.
(d) Can be used for auxiliary or d.c. circuits.

These transformers comprise a three limbed core which are suitably wound with three windings, viz.,

1. Secondary, 2. Operating, 3. Biasing. In Fig. 12:—

0.01—Operating Winding.
S.Sl.—Secondary Winding.
B.Bl.—Biasing Winding.

The operating and secondary windings are wound in a similar manner to the primary and secondary windings of a standard transformer being inductively coupled. The remaining winding, B.Bl (biasing) is wound on the centre limb or alternatively (to obtain more effective control) split on the two outer limbs, but it is not inductively coupled with the other windings. It will be readily observed that the saturation of the iron may be varied considerably by the biasing winding, i.e., it can offer restraint, and the amount varied by (1) the air-gap (2) number of turns. The principle and application of the biasing transformer may be illustrated by the simple diagram, Fig. 13, which shows the application of bias to circulating current protection. In this diagram:

G.W.—Generator Winding.
P.T.—Protective Transformers.
B.T.—Biasing Transformer.
R.W.—Restraining Winding.
O.W.—Operating Winding.
S.W.—Secondary Winding.
R.—Relay.
O.C.B.—Oil Circuit Breaker.
T.C.—Trip Coil.
T.S.—Trip Supply.

The restraining winding (R.W.) is connected in series with the two protective circulating current transformers, and the operating winding connected across points of equipotential in the circulating current system. Under normal conditions of operation, points of equipotential will exist across the operating winding and therefore no

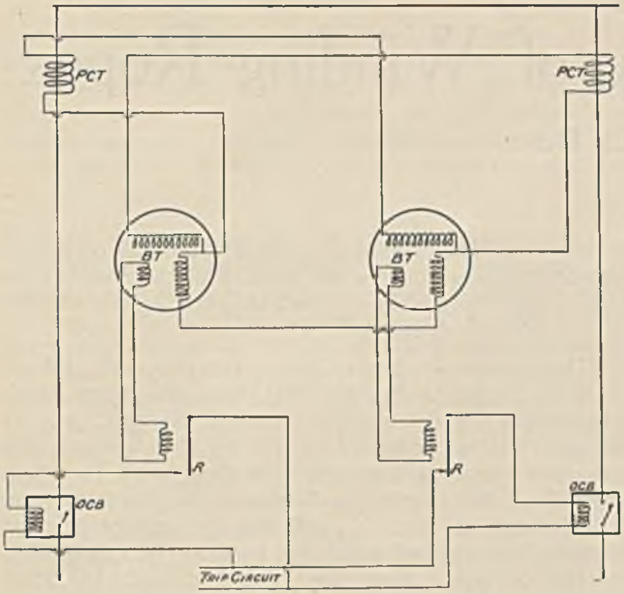

Fig. 14.

currents will flow through it, but under heavy overloads an out of balance may be created in the protective transformers and cause currents to flow through the operating coils. The current passing through the restraining coil, however, prevents the tripping of the relay circuit by the alteration of the coupling between primary and secondary windings. Fig 14 shows the application of the biasing transformers to obtain overload and discriminating restraint.

Arrangements, methods and schemes of protection are so divergent that it is not the intention to eulogise any particular scheme, but with the knowledge and gear possessed by manufacturers at the present time it is quite possible to install a system with a high safety factor, and certainty of discrimination. Where sufficient reactance is not embodied in the apparatus of the system "artificial" reactance is sometimes employed and the correct apportionment is absolutely essential. Wherever employed reactance tends to limit the disturbance on the system beyond it, and to isolate the disturbance from all parts nearer to the supply. A great disadvantage of the employment of reactance is the interference with the voltage regulations, and artificial reactance should not be resorted to unless the inherent reactance of the equipment is insufficient. Reference to the utilisation, arrangements, and advantages of reactance is dealt with in the foregoing sections "Alternators" and "Feeders."

CONCLUSION.

The completion of the grid scheme, and the possibility of Collieries becoming interconnected, will necessitate consideration as to the successful operation under all conditions, since continuity of supply for the sake of safety, is absolutely essential.

The values of short circuit k.v.a. shown in the examples, are instantaneous maximum values, and are considered at normal frequencies. Also the "shorts" are considered across phases, thereby enabling the currents to flow through circuits of defined reactance values, and the effect of phase angle has been neglected. Although the values obtained in some of the examples may be higher than that actually obtained in practice, it ensures the introduction of a factor of safety.

Ⓟ **Correction.**—The Paper entitled "Safety and Efficiency in Mines" read by Mr. W. A. Hutchings before the South Wales Branch and printed in the August number, is eligible for an Association Prize and, therefore, should have been marked thus— Ⓟ

Neglected Opportunities.

We have from time to time, says *The Rhodesian Mining Journal*, deplored the lack of properly trained young Britishers to take up the many fine positions now offering in Northern Rhodesia, as well as elsewhere in South Africa, and it is gratifying to note that several members of the late Empire Congress, have expressed disappointment at the failure of young British-trained geologists, prospectors and mining engineers to get a footing in the new fields. The immense opportunities which have been open during the past few years, and the greatly enhanced future possibilities do not yet seem to be realised by the younger generation of scholars attending the various schools and universities. The consequence has been that the United States copper industry has practically had to be combed to find the right men to place in the highly responsible positions incidental to the founding and building up of an immense new industry, the true proportions of which cannot, even now, be adequately envisaged.

Right well have the American professional men responded to the call, and all honour to them for the splendid manner in which they have applied themselves with characteristic thoroughness to the tremendous problems of development and construction. They have set an example of efficient "hustle," combined with high grade technical skill, to all those who are watching the evolution of a huge mining industry from the Central African bush. But apparently the type of young Britisher required is still not forthcoming in sufficient numbers to take a hand in the great building up which is proceeding, with the consequence that the highest rewards are being distributed outside the Empire.

Personal.

Mr. G. M. HARVEY.

Mr. G. M. Harvey, well known to every member of the A.M.E.E. as its popular President in the 1927-28 Session, has been appointed H.M. Deputy Electrical Inspector of Mines, i.e., Senior Assistant to Mr. J. A. B. Horsley. This newly created position is one well suited to Mr. Harvey's experience and personality: he has had considerable practical experience in the electrification of collieries and for several years past has been the lecturer in mining electrical engineering at the University of Birmingham. Mr. Harvey takes up his new duties on October 1st.

Obituary. Mr. JOSEPH KERSHAW.

On August 25th there passed away Mr. Joseph Kershaw the electrical engineer of the Chamber Hall Colliery, Hollinwood. Mr. Kershaw had for many years been an active member of the Association of Mining Electrical Engineers: he served the office of President of the North Western Branch during the Session 1924-25. The son of a manufacturing chemist, Mr. Kershaw was educated at the Manchester Grammar School: his early business experience was gained in his father's works; afterwards he was employed at the Ferranti works until, at the age of 27, he began at the Chamber Hall Colliery. Mr. Kershaw was 56 years of age.

Electro-Magnetic Testing of Winding Ropes.*

T. F. WALL, D.Sc.

THE problem of testing wire winding ropes by a method which is non-destructive and which permits of rapid and regular periodical tests whilst the rope is in service has been for years a matter of outstanding importance. The Mines Act requires that colliery winding ropes shall be taken out of service after 3½ years, irrespective of their condition. This is a safety precaution governed by the fact that when this Act was framed no non-destructive method was available for testing such ropes. By reason of the requirements of this Act many wire ropes which are capable of considerably longer life are compulsorily replaced by new ropes, and the expense involved in this procedure is very great. For example, winding ropes may cost anything up to about £1400 each, and if it can be proved that such a rope is in good condition after 3½ years' service, an extension of life of even a few months only would obviously lead to a very considerable saving of expense.

There is, however, another aspect of this matter. In some collieries it is the practice, as a further safety precaution, to measure the permissible life of a winding rope by the amount of tonnage raised, in many cases the life so measured being considerably less than the legally regulated permissible life of 3½ years. A reliable method of testing the condition of a winding rope which will enable colliery officials to extend the life from that governed by the tonnage to that permitted by law would result in a further notable saving of expense. It is to be noted in this connection that the life as governed by the tonnage raised is a matter which is directly under the control of the colliery authorities so long as such life is less than 3½ years. The extension of the tonnage life is therefore a matter which can be decided by the colliery authorities without any infringement of the existing legal requirements.

Altogether apart, however, from the question of the permitted life of winding rope, a knowledge of the internal condition of such ropes as obtained by, say, weekly tests, is a matter of vital interest to all concerned in the manufacture and use of these ropes. In this way any incipient flaw can be watched and unexpected damage due, for example, to internal corrosion can be located and examined; the significance of such damage can be assessed and a decision reached as to what action may be necessary to deal with the matter. After several years of intensive research work which has been carried out in co-operation with the Carlton Collieries Association and the British Thomson-Houston Company, an electro-magnetic rope testing apparatus has been developed which meets all the practical requirements. A complete equipment of this apparatus has been installed in the Hatfield Main Colliery, near Doncaster.

The defects which occur in colliery winding ropes in practice may be divided into two main classes as follows:

(1) Broken wires and localised internal corrosion.

(2) Reduction of cross-sectional area extending over a considerable length of the rope. Well known causes of such reduction of area are extended internal corrosion, and external wear due to the rubbing of the rope on the pulleys and the rubbing of neighbouring layers of rope on the winding drum.

Defects due to broken wires are the most difficult to detect owing to the fact that when the wires break they separate only by a very small distance, viz., a distance of the order of $\frac{1}{16}$ in., or the broken ends may even remain butting close up together. The magnetic effect due to the small change in reluctance produced by broken wires is small and can only be detected by means of a method which has been specially developed for this purpose. Corrosion is less difficult to detect electromagnetically, because when corrosion sets in at all, it is practically impossible for it to be confined to such a minute length of rope as, say, $\frac{1}{16}$ in., and the most localised corrosion which is likely to occur in practice will extend over a much greater length than is the case with broken wires.

Reduction of cross-sectional area due to wear and reduction due to corrosion which extends over a considerable length of the rope can be detected by means of the effect of such reduction of section on the magnetic reluctance of the length of rope in which this reduction takes place. In the electro-magnetic apparatus for testing wire ropes the complete routine of testing falls into two parts, viz.:

(a) Testing for broken wires and localised corrosion effects, and

(b) Testing for reduction of section due to corrosion or wear which extends more or less uniformly over a considerable length of the rope.

Of these two tests the first is the fundamental one and the second may be considered as more in the nature of a supplementary test which can be applied should the results of the first test indicate the existence of defects which can be further examined by means of the second test.

It may be noted that the self-balancing search coil S_1 (Fig1), will also detect the commencement and the finish of a flaw in the rope due to extended and more or less uniform wear and (or) internal corrosion.

In the first test an ink-recorder is a practical necessity because, as the rope runs through the magnet system, the highly localised nature of the flaw requires the use of an indicating system which does not depend on the careful observation of every inch of rope passed through, otherwise it would be very easy to miss such a flaw if the attention of the observer were to be momentarily diverted. A further important advantage of an ink-recording device is that permanent records of the tests (see Fig. 6) may be obtained in this way and the history of the condition of the rope throughout its working life may be preserved for reference and any doubtful places may be carefully checked by comparing the records taken on periodic tests.

In the second test, although a permanent record of the test may be obtained as in the first test, it is by no means so essential a feature because from the nature of the flaw the effects of the reduction of section would

*Reprinted from *The Electrical Times*.

extend over a considerable length of the rope and consequently the existence of the flaw will produce an extended effect on the indicating instrument. Moreover, extensive corrosion or extensive wear would be more likely to occur in certain parts of the rope, which may then be specially examined, whereas broken wires may occur anywhere throughout the whole active length of the rope.

Principle of Action of the Rope-Testing Apparatus.

The first essential feature of the electro-magnetic rope-testing apparatus is a magnet system through which the rope passes. This magnet system is excited with alternating current by means of which that portion of the rope which at any moment is near the central part of the magnet system becomes highly saturated. Another essential and characteristic feature of the apparatus is that only a specially selected portion of the total flux which passes through the saturated part of the rope is used for examination and it is by the effect of the flaw on this "search band of flux" that the presence of such a flaw is detected. A special arrangement of search coils is provided, one search coil system being used to detect broken wires and localised corrosion and the other search coil being used to detect extended wear or extended internal corrosion.

In Fig. 1 is shewn a diagrammatical sketch of the magnet system with the search coils in their correct position with respect to the search band of flux. The magnet is built up of laminated iron stampings and comprises a yoke D on which the exciting coil is arranged. The two projecting limbs, C_1 and C_2, are each provided with a tunnelled hole and the rope under test passes co-axially through these hole with a clearance of about $\frac{1}{2}$ in. By reason of the relatively great axial length of the projecting limbs it is possible to obtain a high flux density in that part of the rope which is mid-way between the two limbs, only a moderate number of exciting ampere-turns being required for this purpose. Near the inner face of each of the projecting limbs a groove is provided in a plane at right angles to the axis of the rope, thus forming two narrow slices of the limbs as shewn at A_1 A_2 in Fig. 1.

By means of the grooves B_1 B_2 the portion of the rope which enters and leaves the magnet by way of the limb slices A_1 A_2 is separated from the rest of the flux when it passes through the slices, and it is this portion which is termed the "search band of flux."

The single search coil S_1 is shewn in Fig. 1 embracing both slices A_1 A_2, and thus the search band of flux enters this coil on one side and leaves it on the other. In other words, the total flux embraced by the coil is normally zero and consequently no e.m.f. will normally be induced in this search coil by reason of the alternating flux in the magnet system. That is to say, this search coil is inherently self-balancing. The self-balancing search coil S_1 is used for detecting broken wires and localised corrosion effects, and the action of the coil in performing this function is explained more fully in what follows.

In addition to the search coil S_1, two other search coils S_2 S_2 are shewn in section in Fig. 1. It will be seen that these latter search coils each embrace one of the slices of the magnet limbs A_1 A_2, and consequently each of these search coils S_2 S_2 embrace the whole of the search band of flux. The two coils are connected in series so that the induced e.m.f.'s are additive. The total induced e.m.f. in these two search coils will therefore be a measure of the magnitude of the search band of flux. The two coils S_2 S_2 are used for testing a rope for extended wear or extended internal corrosion. For

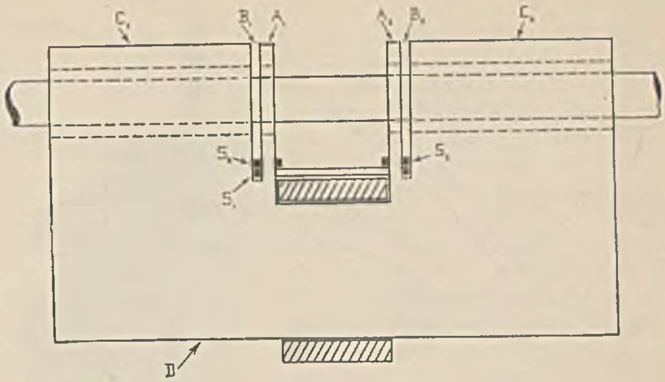

Fig. 1.—Sectional Diagram of the Magnet and Search Coils.

this purpose a suitable high resistance voltmeter is connected across the terminals of these two search coils in series and the reading of the voltmeter will be a measure of the flux through the slice A_1 A_2, and, consequently, a measure of the cross-sectional area of the rope.

If the rope under test is passed through the magnet system and the section of a length which is greater than about the distance between the two slices A_1 A_2, is reduced due to wear or internal corrosion, the total flux passing through the search coils S_2 S_2 will be reduced and consequently the induced e.m.f. will also be reduced correspondingly. The indication of the voltmeter will thus be a direct indication of the cross-sectional area of the portion of the rope which is passing through the magnet system. If required, a recording voltmeter can be used, instead of an indicating voltmeter, for this purpose.

Turning now to the test for broken wires or highly localised wear or internal corrosion, for this test the self-balancing search coil S_1, shewn in Fig. 1, is used. This search coil is wound with about 1000 turns of fine wire and, as already pointed out, by reason of its symmetrical disposition with regard to the search band of flux there is normally no induced e.m.f. developed in this coil, or at most, only a small out-of-balance component. If, however, broken wires exist in the rope, then as that part of the rope passes over one of the slices A_1 A_2, it produces a disturbance of the flux in that slice, the balance of e.m.f.'s in the search coil is destroyed and consequently a resultant e.m.f. appears at the terminals of the search coil. When the defective section is about mid-way between the two slices the flux disposition with regard to the search coil again becomes symmetrical and the balance is restored. When the defect passes across the second slice, a flux disturbance in this slice occurs and a corresponding induced e.m.f. appears at the terminals of the search coil. Owing to the very short length of rope which a flaw due to broken wires extends, say, about $\frac{1}{16}$ in., the passage of the rope through the magnet system at the normal testing speed of about 1 foot per second will produce an e.m.f. which will persist for a correspondingly short time, and consequently it would not be satisfactory in practice to rely on the mere observation of an indicating voltmeter for detecting such a flaw. In this case a recording instrument is practically an essential part of the equipment.

It is further to be noted that since the search coil S_1 is of high resistance and as a 5 per cent. flaw will give rise to an induced e.m.f. of about 0.5 volt, no standard form of a.c. voltmeter can be used to measure this induced e.m.f. since an a.c. voltmeter for a small voltage

Fig. 2.—Test Data for Flux and Penetration at Various Frequencies in a Locked-Coil Winding Rope of 2⅜" Dia.

range will have a low internal resistance and cannot therefore be used in conjunction with a high resistance search coil. Actually, the induced voltage is amplified and rectified by means of a valve set, and in this way a normal d.c. moving coil ink-recorder can be used in conjunction with the valve set to obtain a permanent record of the test.

The use of Alternating Current for the Excitation of the Magnet System.

For the purpose of exciting the magnet system alternating current is essential. Care must be taken that the frequency is such that the flux will penetrate sufficiently completely to the central part of the section of the rope. In this connection it is necessary to distinguish between the "locked-coil" type and the "open-coil" type of winding ropes. In locked coil ropes the outer layers are so formed that the neighbouring wires are locked together, thus completely maintaining the circular form of the rope under all conditions of winding and, apart from its flexibility, a locked-coil rope has almost the appearance of a circular solid rod. The consequence of this peculiar formation of the locked-coil rope is that when magnetised by means of a.c. there will be developed a kind of "skin effect" which will tend to prevent the flux from penetrating to the inner layers of the rope.

A large number of experiments have been made for the purpose of investigating this question of flux penetration, and it has been found that a low value of the frequency is necessary for the exciting current when testing locked-coil winding ropes. The largest size of locked-coil rope used in this country is about 2½ in. diameter and in order to get complete penetration with such a rope it is necessary to use an excitation frequency of not greater than about 9 or 10 cycles per second.

In Fig. 2 curves are given shewing the penetration in a locked-coil rope 2⅜ ins. diameter. As a standard of reference the flux was measured for d.c. excitation by means of a ballistic galvanometer, such excitation, of course, giving complete penetration. In Fig. 2 the total flux is shewn as a function of the exciting ampere-turns on the magnet system. The diameter of tunnelled holes in the magnet limbs was 3⅛ in., thus giving a clearance of ½ in. This sample was taken from a winding rope at Hatfield Main Colliery, and was supplied by Mr. S. Gill.

The relationship between the total flux and the peak value of the exciting ampere-turns is shewn in Fig. 2 for frequencies of 9, 25, and 50 cycles per second respectively. An inspection of these curves shews that for values of the frequency of 25 and 50 cycles per second the shielding effect due to eddy currents is excessively large and consequently the penetration of the flux is too ineffective to make it possible for a satisfactory test on a locked-coil rope of this diameter to be carried out with frequencies of anything like such a high value as 25 cycles per second. An incidental characteristic of the use of such high values of the frequency that the shielding effect of eddy currents becomes large is that the iron losses become excessively large, the rope heats up, and the power necessary for exciting the magnet system becomes notably greater than when lower frequencies are used.

If a supply frequency of about 9 to 10 cycles per second is used it will be seen by reference to Fig. 2 that even for such a large size of locked-coil rope as 2⅜ in. diameter, the penetration is complete when the excitation is greater than about 4000 ampere-turns and even for lower values of the excitation the amount of shielding is quite small. The standard frequency for testing locked-coil ropes has been fixed at 9 cycles per second, since this will be suitable for such ropes of the largest diameter which are met with in practice, and the excitation is so chosen that the peak value of the flux lies well up on the saturated part of the magnetisation curve, e.g., about 4500 ampere-turns in Fig. 2. In order to obtain the requisite low frequency when testing locked-coil ropes a motor generator set is included as part of the standard equipment for the rope-testing installation.

When the open-coil type of winding rope, that is, ropes with hempen or manila cores are used, the conditions in so far as penetration effects are concerned, are entirely different. This is clearly seen by reference to Fig. 3, in which the test data are given for an open type of rope from the Nunnery Colliery, this sample having been supplied by Mr. N. E. Webster.

In this case, the striking result is obtained that for an excitation frequency of 25 cycles per second the flux penetration is complete throughout the whole range of excitation as is evident from the close agreement of the test points taken for 25 frequency and for d.c. excitation (i.e., the ballistic test). Further, even when a frequency of 50 is used for the excitation, the penetration is remarkably complete for the whole range of the magnetisation curve. Only at low values of the excitation, that is, for the magnetically unsaturated condition of the rope, is any shielding effect noticeable, and this so slight as to be quite negligible in practice. The very important result is thus obtained for the open type of winding rope that the normal mains frequency of a colliery electric power supply system may be used

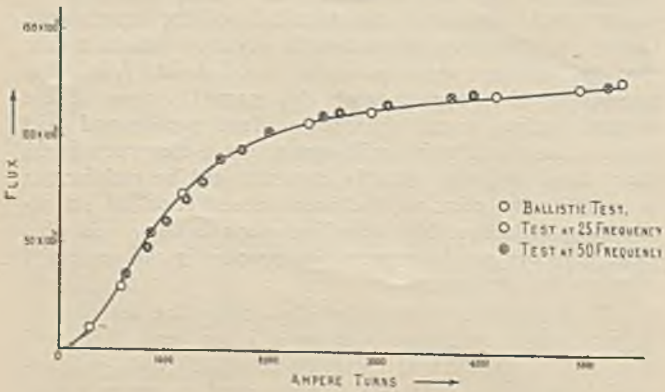

Fig. 3.—Test Data of an Open Type of Rope.

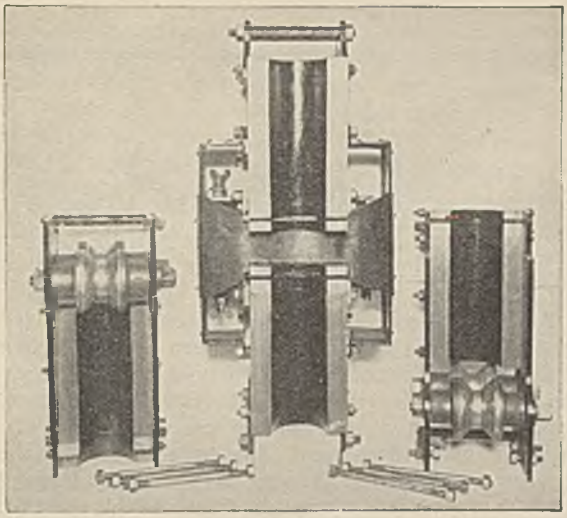

Fig. 4.—The Magnet opened ready for fitting to the Rope.

for the excitation of the magnet. This leads to an appreciable reduction of the cost of the rope-testing apparatus in such cases because a motor-generator set is no longer a necessary part of the equipment: all that is necessary is a static transformer to reduce the supply pressure to the requisite value for the rope-testing magnet system.

The Component Parts of the Standard Rope-Testing Equipment.

The magnet system is so constructed that it can be fitted to the rope *in situ* in a few minutes. This result is achieved by dividing the magnet limbs along the axis of the tunnelled holes. The magnet is fixed at the pit head so that the rope hangs co-axially with the tunnelled holes in the magnet limbs. The removable parts of the limbs are then fixed by means of three bolts per limb, the time required for the whole operation being about ten minutes. Adjustable guide pulleys are provided so that the rope runs freely through the magnet and remains practically co-axial with the tunnelled holes throughout the whole test. The normal speed at which the rope is passed through the magnet is about 1 foot per second, so that the time required for one test run on a rope 1000 yards long is about 50 minutes.

In Fig. 4 is shewn a photograph of the magnet parted ready for fitting to the rope, and in Fig. 5 is shewn a photograph of the magnet system with the rope under test in position.

If the magnet is fitted at the pit head that part of the rope which remains between the winding drum and the pit head when the cage is at the bottom of the shaft does not pass through the magnet. In order to obtain the test results for this part of the rope, the magnet can be removed to the engine house and fitted close to the drum. The photographs given in Figs. 4 and 5 were taken from the magnet system of a complete rope-testing equipment which has been installed at the Hatfield Main Colliery, near Doncaster.

To enable various size of ropes to be tested with one magnet, liners are provided with each magnet. These liners fit in the tunnelled holes, and in this way the requisite diameter of the tunnelled holes is obtained to give a suitable value for the clearance of the rope which it is desired to test. The clearance is normally about ¼ in. to ⅜ in., and is preferably not less than ⅜ in. in order to eliminate any disturbing effects due to slight eccentricity of the rope in the magnet holes.

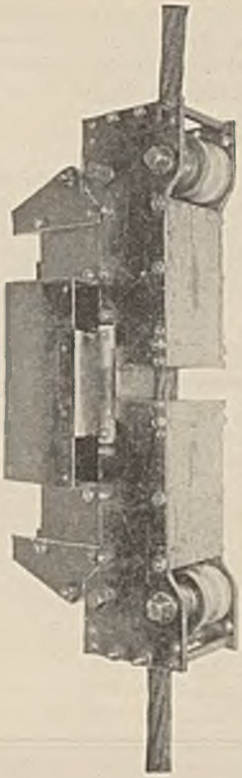

Fig. 5.—The Magnet closed with the Rope in position.

As already pointed out, for testing locked-coil ropes a low frequency a.c. supply is necessary for the excitation of the magnet system. This supply is obtained from a motor-generator set consisting of two induction machines. The motor is a squirrel cage machine directly coupled to an induction generator with a wound rotor. The stator winding of the induction generator is supplied from the normal colliery supply mains and a rotating field is thus produced in the air-gap of the machine. The rotor of the induction generator is driven by the squirrel cage motor in the same direction as the rotating field, and, consequently, by choosing a suitable gear ratio and a suitable number of poles for each machine the requisite low frequency supply for the rope-testing magnet is obtained from the sliprings of the induction generator.

The self-balancing search coil system S_1, Fig. 1, is connected through an amplifying valve set to a recording ammeter. The chart of the recording instrument can be driven at two different speeds, viz., 12 inches per hour and 3 inches per minute respectively. Normally the lower speed is used. If, however, on taking a chart at the lower speed, deflections are found on the chart record indicating flaws in the rope, the defective part of the rope would then be passed through the magnet again, and the recorder speed increased to the higher value. In this way the chart becomes greatly extended and it is possible to locate the exact position of the flaw or flaws in the rope.

The British Thomson-Houston Co., Ltd., have been closely associated with the work throughout the development stages, and have taken part in the design of certain portions of the apparatus. They have also been responsible for the manufacture of certain parts of the existing equipment which has been operating successfully at the Hatfield Main Colliery.

SOME RESULTS OF TESTS ON A ROPE WITH INTERNAL FLAWS.

For the purpose of examining the possibilities of this rope-testing apparatus a length of rope was specially constructed by Messrs. Latch & Batchelor. In this sample several groups of broken wires were included, the position and nature of these flaws being kept secret until after the result of the tests had been obtained.

The rope comprised seven layers of wire as follows:

A central core consisting of			1 wire.
A second layer	"	"	6 wires.
A third layer	"	"	12 "
A fourth layer	"	"	18 "
A fifth layer	"	"	24 "
A sixth layer	"	"	30 "
A seventh layer	"	"	36 "

The total number of wires in the rope was therefore 127, and the overall diameter of the rope was about 1⅝ in. The tunnelled holes in the testing magnet were 2½ ins. diameter, so that the clearance of the rope in the holes was about 9/16 in.

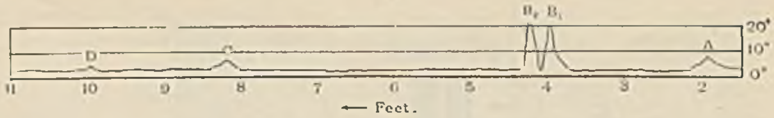

Fig. 6.

In Fig. 6 is shewn the chart which was obtained from the test on this rope. On referring to the record of manufacture of this rope it was found that the several peaks shewn in Fig. 6 corresponded to the actually existing flaws in the rope as following :—

Place in the rope at which the peaks were recorded (Fig. 6).	Actual number and position of the wires broken in the rope.	Percentage of total cross-sectional area of rope which broken wires represent.
A	6 broken wires in the sixth layer	4.7
B_1 B_2	6 broken wires in every layer except the second and seventh	18.8
C	1 broken wire in every layer except the second and seventh	3.2
D	4 broke. weirs in the fourth layer	3.2

It will be noticed that the large flaw at B_1B_2 produces two peaks on the chart. This is due to the generation of an out-of-balance e.m.f. in the search coil system as the flaw passes across each side of the balanced search coil (S_1, Fig. 1) in turn.

An inspection of the results given in the chart of Fig. 6 shews that flaws due to broken wires which give rise to a reduction of area of only 3 per cent. are determinable by this apparatus. In practice, however, it is not likely that a reduction of cross-sectional area of less than about 10 per cent. due to a flaw is likely to be of any serious significance, and the test data given in the foregoing shew that a flaw of this magnitude will produce a very marked deflection of the chart record and can, therefore, be detected with confidence and ease. If, however, it is so desired, flaws which give rise to a reduction of cross-sectional area of only about 5 per cent. can be detected quite readily and by carrying out routine tests at regular periods the development of such small flaws can be watched.

American Flame-Proof Practice.

A circular issued by the United States Bureau of Mines deals with the design of covers for explosion-proof compartments. The Bureau has inspected and tested five types of covers :—(1) covers having two plane surfaces bolted together ; (2) covers having two plane surfaces held together by lugs, clamps, or other means besides bolts ; (3) covers which have screw thread and fit a similar thread in the compartment; (4) covers having plane surfaces with the addition of a tongue-and-groove joint at about the centre of the plane surface and in general secured by hinge pins or similar means of fastening ; and (5) covers in the form of an annular ring accurately fitted to a motor shell which can be rotated around the shell, and thus make easy access to inspection openings in the shell and rotated back again to seal effectively the openings. Tests were also made of large bolted covers having a smaller and more accessible cover within the larger one, which could be opened for inspection purposes.

Bolted covers are used quite generally for compartments that do not require frequent inspection. In designs using wide, properly-machined surfaces with bolts of ample size and with carefully considered spacing, there has been no difficulty in meeting the test requirements. Four schemes of bolting such covers have been adopted : (1) bolts or cap screws using bottomed holes in the compartment ; (2) studs which are screwed into bottomed holes ; (3) studs permanently riveted or welded in place when their removal would otherwise leave through holes ; and (4) bolts which pass through holes external to the compartment made possible by flange designs that extend beyond the casing walls.

The author, Mr. L. C. Ilsley, electrical engineer to the Bureau, considers that other things being equal, bolts and cap screws are preferable to studs or counter-sunk machine screws. In the actual maintenance of equipment trouble has been experienced with studs. Where the threaded parts of the stud extend through the nut, the threads become battered, and when an attempt is made to remove the nut, the stud unscrews from the bottomed hole. Dirt gradually fills in the holes until there is so little depth left for the stud that the threads in the bottomed hole are stripped ; then one must go to a great deal of trouble to replace the stud with the next larger size, redrilling the corresponding hole in the cover. To avoid this trouble, studs should never extend above the nuts. Burrs are also apt to be raised about the stud unless the bottomed hole is recessed.

In the case of flat-head cap screws it is difficult to determine by inspection whether or not the screw is exerting pressure on the cover or has become bottomed before drawing the cover to its seating. Special attention should be given to the length of this type of screw and special care taken that the bottomed hole does not get filled with dirt.

Sliding covers which wedge in place under lugs or merely make close fits under lug projections have been used only infrequently, and have in general proved unsatisfactory in performance, besides being difficult to construct. This type of construction is not recommended. The screw-type cover as originally designed has in every case passed the explosion tests. The reason for this is that, owing to the nature of the zig-zag path through the threaded joint, flame rarely, if ever, passes to the outside of the compartment. Care should be given to the selection of a suitable thread design to permit ready assembly of the cover and to prevent easy damage to the thread in assembling. If large size covers are supported on a hinged bracket to take the weight, it facilitates their handling. In some designs manufacturers have turned off the first one or two threads on the cover to facilitate the starting of the thread particularly on large-size covers. Screw-thread type covers should be locked. It is the usual practice to make the cover of some material that will not rust, such as aluminium or brass.

The tongue-and-groove joint is coming into fairly general use. If properly constructed it can be made very effective and at the same time make the interior of a compartment readily accessible. The importance of correct design is evident from the fact that the first designs, representing the product of four manufacturers, permitted flame to pass and did not meet the test requirements until modified. There are a number of variables that need to be very carefully watched with this type of design, such as the depth and width of the groove, the closeness of the fit of the projection or tongue in the groove, the tolerance in machining that is to be allowed, the method of determining this tolerance accurately, the size and fit of the hinge pins, the degree of contact between the flat-surface portion of joint, and the rigidity of the covers under explosion conditions Such covers should padlocked. This design should not be adopted unless the manufacturer is willing to maintain a rigid inspection system, which will include careful inspection of every compartment made.

The ring-type cover is somewhat special, having been used only on circular-framed motors which could be adapted to this construction. It is rather an expensive design, but one in which ample flange surface can be provided and one that permits of easy and ready inspection.

Three Systems Compared.

Three of the five types of cover described are the most generally used. These are (*a*) bolted, (*b*) screw, (*c*) tongue-and-groove. The advantages and disadvantages of these three types are summarised as follows :—

The advantages of the bolted type of cover are that it permits of a large opening into the compartment, is comparatively cheap to construct and is easy to inspect. The chief disadvantages are the time required for removal and replacement, and the liability to neglect the proper security and tightening of all bolts. The flame path being in only one plane, greater care must be used in both design and maintenance to ensure the retention of flame in case an explosion takes place within the compartment.

The advantages of the screw type of cover when properly made are :—(1) there are no bolts, nuts, and lock washers to be lost or mislaid; (2) with the proper tool the cover can be quickly taken off or replaced ; (3) the threaded joint is probably the easiest of any to make so tight that flame from an internal explosion will not escape ; (4) usually, one can tell by a visual inspection whether the cover is tight enough for safety; (5) the screw cover is simple to lock in place, with either a padlock or some form of seal.

The disadvantages of the screw cover are :—(1) machining threads of large diameters may present difficulties, not so much with the cover itself as with the casting into which the cover fits ; (2) the circular opening may not be adapted for use with the remainder of the design ; (3) the ease with which the cover may be removed may tend to encourage opening the motor at times when opening would be unsafe ; (4) this design does not readily permit of the maximum-size opening into the compartment. Screw-type joints, if not made of different materials, should be lubricated to prevent rusting.

The advantages of the tongue-and-groove cover are : (1) it permits a large opening into the compartment ; (2) there being several directions which the flame must follow, this type of joint should be more effective in stopping flame than the plane-flange design ; (3) there are no bolts, nuts or lock washers to be lost ; (4) the cover can be quickly opened and closed ; (5) this type of cover readily lends itself to locking in place, either with a padlock or some form of seal. The disadvantages of the tongue-and-groove design are that it is expensive to construct and requires a very high order of inspection to ensure that a uniform quality of product is being produced ; moreover, the grooves easily pack with dirt, and if not properly lubricated the joints are liable to rust together.

Integrated Electricity Supply.*

The phrase "integrated electricity supply" means *an inclusion of everything that serves to make an electrical utility complete throughout all the links which lie between its primary source and any point of applied function, no matter where located, how served, or how utilised.* Commonplace phrases of the day in connection with electricity supply are "super-power," "giant power," "interconnection," and "linking up"—all of which are apt to prove misleading in the absence of qualifications, rarely given. In the sense used here, and which it is desired should be understood throughout, the phrase "integrated electricity supply" is not synonymous with any of the foregoing.

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Political schools are never tired of pointing out that the population of Great Britain is dependent for its very existence upon a continuity of foreign trade, meaning thereby the continuous production of manufactured goods for which a profitable market exists abroad. The last five years have proved conclusively, however, that a larger proportion of each succeeding generation in the land will be compelled to look more seriously into the question of earning a living through, or by, an increased development of the internal market ; and once this is conceded, it follows that the present generation has an obligatory duty to-day, in so developing the nation's resources that waste is reduced to a minimum. Such procedure would be coincident with the establishment of conditions whereby the demands of a far larger share of present industrial life than now prevails would be rendered more stable and secure for all concerned, in contradistinction to its present interdependence upon exterior elements, full of insecurities, which render large sections of the population subject to instabilities of tenure and purchasing power over which no control is possible.

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Considered in relation to adverse conditions through which industry has struggled during the period covered by the evidence collated herein, it becomes abundantly clear that, as a whole, and regardless of the time necessary for bringing into force changes of a revolutionary order, the home producing and consuming industry of electricity generation and distribution forms one of the brightest sections of national life, despite the confusion which still surrounds the many issues involved. Post-war conditions have compelled every progressive country to give a greater recognition to this economic aspect, and a slow but sure awakening to the limitless advantages which follow the development of electricity supply is taking place all over the world.

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Coal constitutes the most important element in works cost in British steam generation. Is there any security against similar, or even more extreme, variations (in

* Pointed paragraphs from the paper entitled "Obscured Fundamentals in the Development of Integrated Electricity Supply" by A. Lennox Stanton and Theodore Stevens, presented at the Annual Meeting of *The British Association for the Advancement of Science*, September 9th, 1930.

coal prices) taking place again to the disadvantage of every user of electricity throughout the land? So far as can be seen there is no security.

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Where in the world can be found a similar area so richly endowed as Great Britain with the natural resource, Coal, combined with such wonderful facilities for cheap and rapid transport by land or water?

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Properly integrated development implies close co-operation between all the coal-consuming utilities.

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The next fifteen years should see a growth in the coal industry favourable to the maintenance of permanent prosperity which is conspicuous by its absence to-day.

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No country has its main primary sources of energy more favourably placed than Great Britain for securing a maximum benefit to its population, but where can an area of similar importance be found wherein so colossal a waste goes on, owing to the confusion of issues at work?

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Few vital aspects of national life are of greater importance than those related to the cheap and abundant delivery of forms of energy having their origin in coal.

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Co-ordinating all home coal-consuming interests so as to maintain contracts, to guarantee deliveries, and to ensure freedom from the fluctuations of price, for which no justification exists, would avoid the necessity of holding large stocks.

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Not until the coal industry is placed upon a proper basis as a public utility can many anomalies, under which it now struggles, be removed; and then only can it be organised to fill its right place in the scheme of things. Pending the attainment of this objective, the fundamental part played by coal troubles in steam generation will remain more or less obscure, and this imposes an inability to exercise control over this matter of vital importance in ultimate unit cost.

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The cost trend of steam electric power is still downward as regards both capital and running costs. Technical advances of a high order have been made during the past nine years in hydro practice too, but in their relation to cost elements they do not compare favourably with best conditioned steam practice, particularly when the latter is located nearer the market.

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Little or no evidence is yet available that the problem of extending networks commensurate with the possible demand for domestic heating and cooking is receiving practical attention. Will not a settlement of these problems prove an important factor in advancing the ultimate success of the national scheme? Will not an existing situation of complexity become increasingly burdensome and costly, by reason of a continual lack of adaptable yard-sticks for elements of conversion, load density, and lay-out design? These are pertinent questions calling for early attention on the distribution side, and cannot well be postponed without avoidable loss.

The manufacturers' side of the electrical industry is not only the most highly organised section of the whole, but it also appears as the strongest in its directive influence upon many technical aspects, which, by reason of experience garnered through development, and its bearing upon the ultimate selling price of supply to consumers, represents a field wherein the greatest advantage to development lies in distribution undertakers pooling both their experience and purchasing facilities, to the common advancement of load building.

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Capital and working cost data concerning transmission and distribution, to be of real value, merit extensive amplification both in detail and in scope of application beyond what we are accustomed to find recorded in all current returns.

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Overhead line-work forms another section of development around which many anomalies exist. Disliked by many distribution authorities, having predominant underground interests, the place and function of overhead line-work in the economic scheme of load building has never been properly investigated, and therefore regulations of a restrictive order were never challenged.

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Generally accepted standards of economic construction are not in evidence, and the cheapest and best methods for supplying demands, in rural areas in particular, are not available.

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No compulsory wiring standards are in evidence, and the conditions under which a great deal of the wiring work is carried out are not conducive to the best work, nor always the cheapest, consistent with a satisfactory standard of quality.

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No utilitarian objective has been more fruitful of discord than the subject of charges for electricity. Here, again, has been manifested lack of ability to evolve a system that will prove both clear and simple to the average man and woman as well as satisfactorily comprehensive from the suppliers' point of view.

MINING ELECTRICAL LOCOMOTIVES.

Three electric locomotives for an Australian mine have recently been built in this country. They are of the battery type fitted with motors of 4¼ horse power 40 volts, 1000 r.p.m. The barrel controller gives three speeds in either direction, and bumper-type bars are used at both ends for pin and link. The brakes are of the external shoe type, working on all four wheels, and are hand-operated. The locomotives are for 20 in. gauge, and have a length, for working, of 66¾ in; this can be reduced, with cab folded, to 48 in. overall. Width is 28 in., height 46 in., and wheel base 27 in. The batteries are fitted in sheet metal containers, mounted on rollers to facilitate changing. The gross weight of the locomotives is 30 cwt.: they exert a draw-bar pull of 600 lbs. and have a maximum speed of 4 miles an hour under full load.

AMERICAN TELEPHONE METHODS.

A number of engineers from the British Post Office have visited the United States for the purpose of studying telephone methods, and especially the handling of toll traffic. The party, which included representatives of the Headquarter Traffic Staff, the London Telephone Service and the office of the engineer-in-chief, visited, in the course of a five weeks' tour, long distance and other offices in New York, Washington, Chicago, Buffalo, Detroit, Boston, Springfield and Worcester.