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The Inspectors' Reports.

This year's editions of the Annual Reports of H.M. Divisional Inspectors of Mines, for the year 1930, will surely meet with exceptional approbation. These reports have always been rightly considered as the voice of authority in regard to the interpretation and practical observance of the Rules and Regulations prescribed by Law. They are in effect the vehicles by which the experiences and discoveries of the inspectors are distributed throughout the whole mining industry. The bare recounting of those incidents would constitute a sure guide to officials and men but, when the expert technical knowledge and widespread experiences of the inspectors are voluntarily exercised so fully as to load these reports with a wealth of practical instruction and advice, the gain to the mining community is beyond value. It is in the fullness of appreciation of the useful lessons thus framed by these inspectors round the plain facts of their discoveries that we are prompted to say they have in these latest reports surpassed themselves.

Intensive production and the wholesale conversion of mining practice to applied mechanics create year by year a ceaseless and well nigh overwhelming train of new and extremely difficult problems. Naturally, our particular interests are mainly centred in the engineering plant and appliances of the pit, and so closely does electricity enter into modern developments of this kind that the mining electrical engineer must broaden his study and activities to embrace a very considerable and sound knowledge of the general fundamental principles of following the coal, getting it and loading it away, systematically and and expeditiously—and always retaining safety and profit indelibly in mind as the great essentials. It is doubtful whether there is any textbook likely to be so useful, in respect of general mining information for the power engineer, as are these reports.

Take, for example, the instruction offered concerning falls of ground. Several of the inspectors give prominence to the methods of roof support and particularly at gate ends and the working face, where most of the accidents from falls occur. They describe in detail, with many drawings and photographs, the actual conditions in particular cases : the methods which have, sometimes with tragic consequences, proved faulty and the correct safe methods which have been applied. Quoting from a report : "Established practice and routine should not be accepted and perpetuated as handed down by tradition without constant review in the light of changing conditions, increasing knowledge and new methods and types of support." The rapid advance of the face, the greatly increased usage of face conveyors and other face machinery in general, have imposed an extremely severe demand upon the ingenuity and engineering skill of the responsible technical staff. Steel props, straps and arches are rapidly ousting timber, the recorded remarkable increase in the vogue of steel proves the efficacy of the new method, in some cases the limit to further progress has been set only by the demand exceeding the supply. The manipulation of steel sections is an engineers' job—and the work done in this direction as described so fully in detail in these reports is work as actually applied. Thus the information given is of that concise matter-of-fact nature which, to the practical mining engineer, is so much more valuable than the study of text books.

A large increase in the use of electric chain coalcutters is indicated. The tendency to use longer jibs on these machines is a matter of some concern in that they of necessity leave a wider span of unsupported roof between the last line of props and the back of the holing. It is hardly possible to see how this risk can be safeguarded and it is suggested that it might be necessary to limit the length of the jib unless some new safe method of working off the coal per cut is devised. It is further suggested, however, that the length of the jib may not, after all, need to be limited because of the danger of large areas of unsupported roof, since it would appear that in some cases the rate of advance of the face has grown so rapidly as to be disproportional to the facilities for getting the coal away.

The coal cutter has always been a source of danger by reason of men accidentally or carelessly getting foul of the running cutters. The design of efficient chain guards has long exercised the ingenuity of the machine makers and operators. It is gratifying to note from the several illustrated details given in the reports, coupled with the expressions of criticism and approval, that a number of these attachments are provedly successful and are now being provided by the makers as standard with their respective machines.

Haulage conditions too become increasingly difficult with the march of intensive mining. The inspectors state that the mines are not, in this respect, keeping pace with the requirements. The difficulties to be faced are mainly of an engi-

neering nature. Larger steel supported roadways must be more generally provided and, in particular, improved methods of signalling are demanded.

As to the electrical failures and accidents mentioned in these reports, it can be said that they were neither exceptionally numerous nor remarkable during the year. They still shew that personal carelessness and ignorance are usually the primary causes: which is extremely regrettable in one sense, but from which can be derived a stimulated encouragement to proceed further on the obvious right lines with the promise of a certain increasing success. The report of H.M. Electrical Inspector will cover this part of the mining history for 1930, and we shall probably have occasion to refer more specifically to that at a later writing.

It is only possible here to indicate in general terms the reasons why these reports should be universally read in mining circles. We cannot at the moment refer specifically to any particular accident or series of accidents—but it is to be noted that whenever the inspector has applied himself to drawing board and descriptive detail he has done so because an accident has actually occurred and he has felt himself dutifully impelled to give freely and of his best to prevent recurrence and to couple his warnings with reasoned and dependable instructions.

NEW BOOKS.

H.M. STATIONERY OFFICE.

The following, printed and published by His Majesty's Stationery Office, can be purchased through any bookseller or directly from H.M. Stationery Office at the following addresses: Adastral House, Kingsway, London, W.C. 2; York Street, Manchester; 1 St. Andrew's Crescent, Cardiff; 120 George Street, Edinburgh; or 15 Donegall Square, W., Belfast.

MINES DEPARTMENT.—OUTPUT AND EMPLOYMENT AT METALLIFEROUS MINES, QUARRIES, etc., during the Quarter ended 30th June, 1931. Price 4d. nett.

MINES DEPARTMENT.—REPORTS OF H.M. INSPECTORS OF MINES under the Coal Mines Act, 1911, for the Year 1929. Price, each report, 1s. nett.

1.—Scotland Division: Report by Mr. J. Masterton, O.B.E.

2.—Northern Division: Report by Mr. T. Greenland Davies.

3.—Yorkshire Division: Report by Mr. E. H. Frazer, M.Sc.

4.—North Midland Division: Report by Mr. J. R. Felton, O.B.E.

5.—North Western Division: Report by Mr. W. J. Charlton.

6.—Cardiff and Forest of Dean Division: Report by Mr. Macleod Carey, O.B.E.

7.—Swansea Division: Report by Mr. T. Ashley.

8.—Midland and Southern Division: Report by Mr. W. E. T. Hartley.

also—Reports by H.M. Inspectors of Mines and Quarries under the Quarries and Metalliferous Mines Acts: in one volume, price 1s. nett.

FIREDAMP EXPLOSIONS AND THEIR PREVENTION by W. Payman (Safety in Mines Research Board) and I. C. F. Statham (Professor of Mining in the University of Sheffield): with a Preface by Prof. R. V. Wheeler, D.Sc., F.I.C. (Director of Research, Safety in Mines Research Board). London: Humphrey Milford, Oxford University Press.—Price 12s. 6d. nett.

Colliery managers and engineers, as well as the manufacturers of mining electrical appliances, will welcome this book which so effectually crystallises the bewildering mass of literature and published opinion which has gradually piled about and obscured the realities of the subject dealt with. It is, indeed, rather a surprise to note how well the authors have been able to concentrate their materials down to all that is really of consequence—the plain technical facts concerning these mining risks with which every practical colliery official must become familiar: for the book is but of moderate size, clearly printed in open type, and quite reasonable in price.

The authors enjoy an international reputation as leading authorities in these matters and so closely are they linked in the chain which unites the legislature with the mining industry of this country that the British colliery official will be disposed to accept their writings as in the nature of an infallible safe reference—and in doing so he cannot go far wrong.

To indicate the scope of the ground covered the respective titles of the main chapters may be quoted. Firedamp: Testing for Firedamp: Official Tests for Safety Lamps: Testing of Bells, Relays and Telephones: Testing of Shotfiring Apparatus: The Design of Flameproof Electrical Apparatus for use in Coal Mines: The Testing of Flameproof Electrical Apparatus: The Testing of Coal-Mining Explosives in Foreign Countries and in Great Britain: Substitutes for Explosives.

A very valuable feature is the interpolation of relevant excerpts from British Regulations and Orders and from similar Official Rules of the Continent and America. Naturally a very considerable part of the book is devoted to electrical practice, and it is in this connexion that the majority of readers will doubtless find the greatest value. So rapid has been the progress of mining electrical developments, and so confusing the claims and opinions advanced by interested parties, that the colliery official has often longed for some trustworthy aid towards a clearer understanding of these electrical problems. He will find it here, not in the mere quotation of official rules but in the informed interpretation of those rules coupled with the concise expression of reliable opinion. For example, it is indicated that the early types of lighting fittings and flexible cables introduced such an element of danger that face lighting from the electric power mains was not generally permitted. The authors' comment is that lighting from power mains offers many advantages from the standpoints of safety, health and efficiency—and that recent developments in the design of flame-proof lighting fittings for face use have so far progressed that there is now no reason why this method of illumination should not be increasingly employed in future.

It is by this style of quoting the letter of official requirements, the statement of the results of tests and research, descriptions of the principles of design introduced in modern appliances, and the final logical summation of the expert that the mining engineer is enabled to derive a safe and dependable understanding of matters which are of extreme importance and which involve so much complexity in detail.

ECONOMICS OF COAL CLEANING.

R. D. ROGERSON.

It is seldom possible to work a seam of coal without including in the winnings a quantity of dirt. Though some of the dirt is sorted out from the coal underground and left in the goaf, some is loaded with the coal and sent to the surface. In separating the dirt from the coal underground a loss of coal may be sustained as it is impossible for the miner in the dim light of a miner's lamp accurately to distinguish between certain portions of dirt and coal.

The removal of dirt from the raw coal sent to the surface (for which the costs of winning, loading, haulage and winding have already been incurred) involves the colliery company in the cost of picking and washing and in many other incidental expenses. During these processes, a large portion of the output may be rejected as refuse, and the saleable coal tends to be reduced in size. The actual cost of production per ton of saleable coal is increased in direct proportion as the amount of refuse removed from it is increased, and the tendency to reducing the size of the coal lowers its market value as, at present, large coal commands a higher price. It is therefore inevitable that the producer should consider the optimum recovery of saleable coal of more importance than the marketing of the cleanest possible product.

At the present time relatively little coal is sold to a specification, and it is in the producer's interest not to remove from the coal such dirt as the buyer is willing to purchase. It is reasonable, therefore, that the colliery owner should look upon the cleaning of coal with disfavour except in so far as it enables him to obtain or retain markets which he otherwise would lose ; and that, unless the consumer is prepared adequately to remunerate him, he should confine his washing operations to that minimum which permits of the sale of his coal.

Although it is generally agreed that the consumer is willing to pay for the removal of this incombustible material in proportion as the heating value of the residual coal is increased, the full extent of the benefits that would accrue to the consumer are not perhaps, adequately realised. Incombustible material in the fuel reduces its calorific value, although the additional value of the purer fuel is, for almost all purposes, considerably greater than is suggested by a comparison of the calorific values of the two fuels ; the weight that must be handled and transported is increased, giving rise to difficulties of combustion which renders the heat less easily available, occasions loss of combustible material, and involves further expense in its disposal.

The disadvantages of a high-ash coal are not confined to the consumer, but are also inflicted upon the general public, because ash in coal increases the production of smoke and results in the discharge of fine dust from chimney stacks, especially where pulverised fuel boilers are used. The harmful effect of the ash in coal used for various purposes and the advantages which a purer coal, as obtained by coal cleaning, would bring in its train, are described briefly below.

Fuel Used for Domestic Purposes.

When coal is used for domestic purposes the bulk of the ash occurs as "fixed" ash in the coal, though large pieces of free dirt are frequently found, the removal of which irrates a householder, and in large cities involve considerable expense in removal. The principal alternative, however, to domestic coal is gasworks coke which is usually dirty. Gas companies recommend their coke for its smokeless qualities but it is not fully realised that the domestic consumer is usually far more likely to purchase a coal because it burns in an open grate without leaving large quantities of ashes behind, than because it ensures the maintenance of a clear atmosphere above his chimney top. More customers would probably be attracted if the coke could be recommended for its ashless qualities, and such customers would be prepared to pay a higher price if it reduced domestic labour and expense. Apart from the labour of dusting the rooms after clearing away the ashes, and the damage to carpets and furnishings by the gritty particles of ash, there is a definite reduction of thermal efficiency of the fire when the coal contains quantities of incombustible matter. Bligh and Hodsman, for example (Journ. Soc. Chem. Ind. 1927, 46, 92T), found that the radiant efficiency of a domestic coke fire was 29.3 per cent. with a coke containing only 1.5 per cent. of ash, whereas with a similar coke containing 5.5 per cent. of ash the radiant efficiency was only 23.9 per cent. and they attributed the decreased efficiency with the coke of higher ash content to a film of incombustible material formed over the surface of the particles. An increase of 5.4 per cent. in the utilisation of the potential heat of the coke was obtained by reducing the ash content of the coke by only 4 per cent.

Steam Generation in Boilers.

Although bad boiler design and poor operation cause considerable loss in steam generation, by far the greatest loss is in thermal efficiency. Thermal losses may be tabulated as follows :

(1) Radiation of heat from the body of the boiler plant.
(2) Heat required to evaporate the moisture in the coal.
(3) Unburnt carbon withdrawn in the ashes.
(4) Unburnt carbon carried away in the flue gases.
(5) Sensible heat of the flue gases.
(6) Sensible heat of the ashes when withdrawn.
(7) Combustible gas in the flue gases.

For each of the last five causes, a greater loss of efficiency is experienced in using a coal of high ash content than when using a coal with a low ash content. When a coal of high ash content is used a greater amount of ashes is produced, and the loss of sensible heat, and of combustible matter in the ashes, will, in consequence, be greater. It also leads to greater loss in the flue gases.

The irregularities of the depth of the fuel bed on a boiler grate causes too much air to be passed where the bed is thin and too little where the bed is thick. The air supply must be regulated to meet the needs of the thicker parts of the bed in order that the formation of smoke will be prevented, with the result that an excess of air passes through the bed where it is thin. The greater part of this excess air appears in the flue gases, carrying away sensible heat with it.

To prevent a high loss of fuel in the flue gases, either as CO or as smoke, it is necessary to pass some excess air through the fuel bed, but if the quantity of excess air is too great, smoke formation is induced owing to the air causing a local reduction in the temperature above the fuel bed thereby opposing complete combustion. The gases passing over the fuel bed are then insufficiently heated and imperfectly burned. The time available for proper combustion is reduced, because, the greater is the amount of excess air, the more rapidly do the gases above the fuel bed pass into the flues.

The speed with which the air passes through the thinner portions of the fuel bed causes small particles of solid fuel to be lifted from the fuel bed, and these combustible particles pass into the flues in an unburnt state. These solid particles also tend to stick to the crown of the furnace, and, with some coals, the ash fuses at the high temperature of the crown and the refractory lining of the furnace is eroded.

These losses of heating power in boilers are common to all boilers whether fired by hand, by a mechanical stoker, or by pulverised fuel and the losses are increased considerably if the boilers are called upon to perform more work than the normal rated duty.

The effect of using a coal of high ash content can now be examined. A hand-fired boiler, which is of course the least efficient of the three types mentioned, is affected to the greatest extent. More frequent firing of the boiler necessitates the more frequent opening of the fire doors, and at such periods the excess air admitted over the fire cools the burning gases, producing smoke which in itself is heated, causing a loss of sensible heat. It is necessary to rake the fire and to clinker at shorter intervals, again allowing the entry of cold excess air above the fire, and causing a much greater amount of combustible material to fall through the fire bars and be lost. It is also necessary to work with a greater depth of fuel bed, which aggravates the difficulties of maintaining an even bed and greatly increases channelling, and the losses of sensible heat and combustible matter caused thereby. Mechanical stokers are unable to deal with coals which clinker easily owing to it sticking in the grate and interfering seriously with the draught. This difficulty can be met with by steam injection, but it is considered more serious if a coal of high ash content is used.

An increased amount of ash in the fire also increases the resistance to the passage of the air and deadens the fire, renders a break-through of excess air in a weak part of the bed much more likely, and causes a greater loss of combustible matter in the ashes. If the boiler plant is required to meet a sudden demand, the fire is less able to respond to an increased rate of feed, and the percentage loss of combustible matter in the ashes increases rapidly. Not only does a high ash coal increase the losses of sensible heat due to the passage of excess air, but it also increases the loss of combustible particles in the flue gases, and in the ashes.

The use of low-grade fuel has been specially recommended for use in pulverised-fuel boiler firing, but where the coal could be cleaned before use, the efficiency would be greater, and the cost of cleaning a very profitable expenditure. When a high ash coal is used for pulverised fuel firing, the cost of drying is correspondingly increased, and the cost of grinding and wear and tear of the pulveriser are disproportionately increased because the shale is harder to grind than the coal. Furthermore, the mineral matter in the dust entering the combustion chamber must be heated to the flame temperature without contributing anything to the heating, and the incombustible dust must be discharged from the furnace. Generally the flue gases carry with them large quantities of incombustible dust and discharge them from the stack into the atmosphere, and numerous are the complaints against this nuisance.

Mineral Matter in Coke for Blast Furnaces.

The disadvantages of ash in the coke fed to a blast-furnace may be tabulated as follows:

(1) Fixed carbon in the fuel reduced.
(2) Use of additional fuel and limestone for smelting.
(3) Reduces the hardness and resistance to abrasion in the coke produced (especially from inferior coking coals) and thus increases the proportion of breeze.
(4) Available heat in the hearth reduced.

A further serious disadvantage of the ash contained in the coal when fed as coke to the blast-furnace is the liability of the iron to be contaminated by other elements, such as sulphur, phosphorous and arsenic.

When a coke is used with a lower ash content the following improvements take place:

(1) Reduces the labour cost.
(2) Decreases the consumption of coke.
(3) Improves the quality of the iron.
(4) Increases the ease of operation of the furnace.
(5) Increases the output and thereby reduces standing and capital charges per ton of pig.

Because of the multiplicity of the factors involved, it is difficult to evaluate the additional cost imposed upon blast-furnace operations by the ash in the coke. Apart from its lower thermal value, the principal objection to the ash is the increased amount of slag produced, and the extra quantity of limestone and fuel required to convert the ash into slag. The constituent of the ash to which this may be chiefly attributed is the silica.

Assuming that the coke contains 10 per cent. of ash, and that the ash contains 40 per cent. of silica, the extra amount of silica (over and above that contained in the iron ore) charged into the furnace is equivalent to 1 cwt. of silica per ton of pig iron produced. Taking the figures of Ridsdale (Journ. Iron and Steel Inst., 1920, 101,1,176), the extra solids required to be handled for a slag basicity of 2 amount to ½ ton for every ton of pig. Ridsdale's figures for the effect of charging 1 cwt. of silica into the furnace are as follows:

Slag basicity	2.0	1.8	1.7	1.5 cwt.
Limestone required	4.12	3.68	3.47	3.04 cwt.
Coke required	2.42	2.20	2.09	1.86 „
Total extra solids charged ...	6.54	5.88	5.56	4.90 „
Slag produced	3.47	3.20	3.09	2.82 „
Total solids to handle ...	10.01	9.08	8.65	7.72 „

Lewis (Journal West of Scotland Iron and Steel Inst., 1924-25, 33, 2) calculates the additional cost resulting from the presence of the ash-forming materials in a splint coal used for Scotch blast-furnace practice. Taking a standard limestone of the following composition:

CaO	54.32	per cent.
CO_2	42.68	„ „
Impurities	3.00	„ „

the lime available as flux is 51.44 per cent. for 2.88 per cent. is required as flux for the impurities in the limestone itself. Assuming the coal to contain 5 per cent. of ash, and that the ash contains 8 per cent. of lime, a portion of the ash is self-fluxing; and with a slag containing 49 per cent. of lime, the amount of self-fluxing ash is:

$$\frac{8}{100} \times 5 \times \frac{100}{49} = 0.82 \text{ per cent. of the coal.}$$

The remaining mineral matter amounting to 4.18 per cent. of the coal requires:

$$\frac{4.18 \times 49}{(100 - 49)} = 4.01 \text{ per cent. of lime}$$

$$\text{or } \frac{4.18 \times 49}{100 - 49} \times \frac{100}{51.44} = 7.81 \text{ per cent. of limestone.}$$

From this calculation it follows that 7.81 cwts. of limestone is required to flux the 1 cwt. of ash in the coal

(5 per cent.) and that the slag made from the coal ash alone amounts to 0.82 + 4.18 + 4.01 =9.01 per cent. (nearly 2 cwts. per ton of coal). Taking the estimate of Joseph and Read (Trans. Amer. Iron and Steel Inst., May 1924) that every pound of slag requires over half a pound of coke to melt it, it follows, that the slag from the coal ash requires $9.0 \times \frac{1}{2} = 4.5$ per cent. of the coal for fusion purposes.

The loss of carbon is not confined to the amount required to flux the coal ash, but a further quantity is required to flux the impurities in the extra limestone that must be added and the solution of carbon in the carbon dioxide from the limestone causes an additional loss. Taking these losses into account, Lewis concludes that for every 1 per cent. of ash in coal above 5 per cent. the value of the coal is reduced by 9.4d. per ton. Assuming this figure, and allowing for other extra expenses, the extra cost per ton of pig iron made is equivalent to an additional cost per ton of pig as follows :

Per cent. ash in Coal.	*Extra Cost in Pence.*
5	—
6	16.83
7	34.44
8	52.90
9	72.28
10	92.62
11	114.02
12	136.56

Various tests were carried out by the Consett Iron Co., Ltd., with varying ash contents in the coke, and it was found that the greatest trouble arose from fluctuations in the average ash content of the coke supplied to the furnaces. For 1 per cent. reduction in the ash content of the coke, the output of the furnace was increased by 6.4 per cent. while the coke consumption was reduced by 0.42 cwt. per ton of pig respectively. It was estimated that the saving in coke alone amounted to 1s. 3d. per ton of pig for a 3 per cent. reduction in the ash content of the coke, and if other factors were taken into account the saving would probably amount to about 2s. 3d. per ton of pig.

High Ash Coal in the Carbonisation Industries.

Because of the presence of incombustible matter in the coal, certain difficulties arise in the manufacture of by-product coke. The presence of chlorides is very harmful to the oven walls, unless they are made of silica, and the presence of iron tends to reduce the ammonia yield. The principal disadvantage, however, is the production of breeze in the coke. Breeze always contain a higher percentage of ash than the larger coke, and it is obvious that it results from the presence of slurry in the coal. The slurry usually contains at least 20 per cent. of ash and about 30 per cent. of water, and includes much fusein and clay slimes, which prevent the agglomeration of the slurry into a hard coke. The weak product which results is easily disintegrated and accumulates in the breeze collected at the coke-oven plant. Unscreened coal is used to a very large extent in the gas industry and it sometimes yields a coke containing as high as 15 per cent. of ash. With modern developments in coal cleaning there is no excuse for this practice being continued.

In modern gasworks carbonisation a portion of the coke is gasified in producers and the remainder is sold as a domestic fuel. The removal of the clinker from the producers and its disposal is an expensive charge on the gasworks, and, in large towns where it may be necessary to transport for reasonable long distances, may amount to four or five shillings per ton of ashes.

The incombustible mineral matter is, moreover, a source of trouble and expense in the operation of the producer. The higher the ash content of the coke the more frequently is it necessary to clean the fires and remove the clinker, and the gas-making capacity of the producer is correspondingly reduced. Further disadvantages of high ash fuels are the increased amount of combustible matter lost in the ash and the rapid increase in the resistance to the flow of air and steam through the fuel bed between clinkering periods. The channelling which occurs when the resistance increases occasions additional difficulties because it causes fine solid particles to be carried forward with the gas.

Similar difficulties are experienced when the coke is used for the manufacture of producer gas for metallurgical purposes. Moreover, in the gas retort, the yield of gas per ton of coal is reduced by the presence of dirt in the coal charged and the sulphur content of the gas may be increased.

Ash in Bunker Coal.

The chief objections to ash in the coal used for bunkering are those common to all coal used for steam raising purposes. There are, however, two additional objections. Uncleaned coal contains a higher percentage of pyrites than cleaned coal, and although pyrites may not, in the majority of cases, be the primary cause of spontaneous combustion, there is little doubt that it is, or can be a contributory factor. Another objection is the extra cost of bunkering and the loss of cargo space. A reduction in the ash-content of the coal will in most cases, effect a considerable saving. For example, if 200 tons of coal containing 10 per cent. of "free" ash is bunkered at a cost of 1s. per ton, 20s. is spent on loading useless material and an extra 20 tons of dead weight is carried which, at a freight rate of 1s. 9d. per ton per day, is equivalent to a loss of earning power of 35s. per day or about £500 per annum.

Railway Fuel.

Railway companies have for many years realised the value of a coal with a relatively low ash content, because of its higher calorific value and the increased boiler evaporation per square foot of grate area. They have, for these reasons, always been willing to pay a higher price for lump coal, which, besides being easier to stack and less liable to spontaneous combustion, almost always has a lower ash content than the smaller sizes. Before the coal is used for locomotive firing, however, it is broken up, and usually moistened so that, except for the greater ease, and safety from spontaneous combustion in storage, small and moist coal, provided it were clean, would serve their purpose equally well.

Purchase of Coal on Calorific Value.

It may be accepted without reservation that coal has a higher value to the consumer the lower its ash content, but this is not the only quality of a high grade fuel. The principal factor governing the commercial value of a coal should be its suitability to meet the consumer's requirements. A coal which is an excellent coal for steam-raising would not have any great value for the manufacture of blast-furnace coke, and a good coking coal is almost useless for the manufacture of water gas.

Apart from consideration of size the principal factors which govern the suitability of a coal for any given purpose are its volatile matter content, its coking properties and the fusibility of its ash. These properties

depend upon the chemical composition of the coal and of its inorganic constituents.

To correlate the chemical composition of different coals with their observed behaviour on combustion or on submission to thermal decomposition (carbonisation or gasification) various schemes for the classification of coals have been proposed from time to time. Those which are now regarded as having the greatest value, either for scientific purposes or in connection with the industrial utilisation of the coal, are Seyler's classification and Parr's classification. Seyler divides coals into genera according to their hydrogen contents, and each genus is divided into different species according to the carbon contents of the coals. The classification thus provided enables the properties of the coals to be predicted with remarkable success from their ultimate analyses. Parr's classification is based on calorific values of the coals and their volatile matter contents, and the groups into which the coals are found to fall when classified on this basis are found to correspond roughly, with the groups of Seyler's classification.

For the scientific classification of coals it is necessary to eliminate the effects of those ingredients of pit produce which are essentially extraneous to the pure coal substance, and for this purpose several formulæ have been proposed. The ingredients whose effect must be eliminated are ash, free moisture in the coal, sulphur present as pyrites, and the carbon present as carbonate. Each of these ingredients either increases or lowers the observed calorofic value of unit mass of the "pure" coal substance or the carbon content determined by combustion.

Standards have been proposed as a means of expressing analytical results in such a form that they may be utilised for scientific classification. Seyler suggests that the results should be corrected to "pure coal" by multiplication by the factor :

$$\frac{100}{100 - (\text{Ash} + \text{Moisture} + \text{Sulphur})}$$

Parr proposes a formula to calculate the calorific value of the coal : Calorific Value =

$$\frac{\text{B.Th.U. Indicated} - 5000\ \text{Sulphur}}{1.00 - \left(\text{Moisture} + 1.08\ \text{Ash} + \frac{22}{40}\ \text{Sulphur}\right)}$$

Moisture, ash and sulphur being their weights in unit mass of the coal.

Allowance is thus made in the calculation for the heating value of the sulphur and for the presence of hydrate water in the ash, the ash being multiplied by 1.08 for this purpose. Some such formulæ are required as a basis for the purpose of determining the class or group into which the coals fall, and in order to indicate their suitability for a certain industrial use.

(*To be continued.*)

Mines Department: Safety Conference in Manchester.

Mr. Isaac Foot, M.P., Secretary for Mines, announces that a General Conference on Safety in Mines, representative of all those engaged in the coal mining industry in Lancashire, Cheshire and North Wales, will be held under his Chairmanship at Manchester on Saturday, the 5th December, 1931. Addresses will be given by :

Sir Henry Walker, C.B.E., LL.D., H.M. Chief Inspector of Mines, on "Ways and Means for Increasing Safety in Mines."

Mr. W. J. Charlton, H.M. Divisional Inspector of Mines, on "Ventilation."

Professor R. V. Wheeler, D.Sc., Director of the Research Stations under the Safety in Mines Research Board, on "Explosions"; and

Major H. M. Hudspeth, D.S.O., M.C., M.Sc., Mining Engineer to the Safety in Mines Research Board, on "Falls of Ground".

The addresses will be followed by questions and a discussion which will be confined to matters affecting safety.

Electric Cap Lamps.

Prof. W. H. McMillan in the course of a paper read in Nottingham on Nov. 7th before the Midland Branch of the National Association of Colliery Managers dealt with experimental work he had recently done with a view to determining the respective values of reflectors and glasses of various types for cap lamp usage. As a result he was able to formulate the following conclusions.

(1) The combination of a clear glass and matt white reflector, or a frosted prismatic glass and matt aluminium reflector, gave the most uniform distribution of light, but the average illumination was considerably less than in other combinations.

(2) The polished reflector and clear glass gave the maximum average illumination, but the distribution was very unequal, and resulted in an intense beam over a small area in the centre of the illuminated area, with alternate bright and dark bands towards the outside of the area.

(3) The combination of a lightly frosted glass and a matt aluminium reflector gave fairly uniform distribution : there was a slight loss of light, but the effect of glare was greatly reduced.

(4) The cap lamp, because it was nearer the work, gave a greater average illumination over a working area, 5 ft. in diameter, than was given by a high candle-power handlamp over a working area 8 ft. in diameter.

Costs of Petrol from Coal.

Mr. K. Gordon of Imperial Chemical Industries Ltd. in a recent address said that the only known method of obtaining hydro-carbon oils and spirit from coal was by hydrogenation. His firm had designed a plant for an annual production of 200,000 tons of petrol : a quantity representing about eight per cent. of the yearly consumption of petrol in this country. The works' nett costs, not including any profit, for making the petrol amounted to 7d. per gallon. The present price of imported petrol is only 2½d. per gallon, whereas the cost of coal alone amounts to 2d. per gallon of the petrol yielded therefrom. The plant referred to had been built with a view to relieving unemployment, restoring the national trade balance and to free this country from an entire dependency upon overseas supplies of mineral oils in the event of international emergency. Mr. Gordon said there was no visible prospect of oils made from coal competing with the imported natural oils.

HENLEY'S NEW BRANCHES.

W. T. Henley's Telegraph Works Co., Ltd., have opened new Branch Stores at Nottingham and Burnley. The Burnley Store was opened on November 2nd under the charge of Mr. R. H. West and the address is Victoria Mill, Trafalgar Street. The telephone number is Burnley 3682. The Nottingham Store was opened on November 9th under the charge of Mr. J. W. Bayliss, the address being Park House, Friar Lane, and the telephone number, Nottingham 4470.

Proceedings of the Association of Mining Electrical Engineers.

A.M.E.E. COUNCIL MEETING.

A meeting of the General Council was held on October 10th last in Sheffield. There were present:

Major E. Ivor David, President, in the Chair; Mr. W. T. Anderson, Past President, Certification, Underground and Surface Lighting Committees; Mr. M. Brown, Past President; Mr. J. W. Gibson, Past President, Certification, Examinations, Papers, Underground, and Surface Lighting Committees; Mr. G. M. Harvey, Past President, Examinations Committee; Mr. R. Holiday, Past President, Treasurer; Mr. D. Martin, Past President, Advisory Committee; Mr. A. B. Muirhead, Past President, Advisory, Certification, Underground and Surface Lighting Committees; Mr. G. Raw, Past President, Certification and Finance Committees; Mr. T. Stretton, Past President, Advisory, Underground and Surface Lighting Committees; Mr. F. Beckett, Vice-President, Finance Committee; Mr. R. Ainsworth, Vice-President, Publications Committee; Mr. A. W. Williams, Advisory and Publications Committees; Mr. H. J. Fisher, Certification, Examinations, Underground and Surface Lighting Committees; Mr. W. Bolton Shaw, Certification and Papers Committees; Mr. T. H. Williams, Certification, Examinations and Prizes Committees; Mr. G. E. Gittins, Examinations Committee; Mr. A. C. MacWhirter, Papers Committee; Mr. S. H. Morris, Papers and Publications Committees; Mr. S. A. Simon, Papers Committee; Mr. J. R. Cowie, Prizes Committee; Mr. A. Dixon, Prizes Committee; Capt. I. Mackintosh, Prizes Committee; Mr. I. T. Dixon, Underground and Surface Lighting Committee; Mr. A. V. Heyes, Underground and Surface Lighting Committee; Mr. W. Webster, Lothians Branch; Mr. J. Walker, Lothians Branch; Mr. H. M. Hodgart, West of Scotland Branch; Mr. J. R. Laird, West of Scotland Branch; Mr. A. F. Stevenson, West of Scotland Branch; Mr. E. E. Shatford, North of England Branch; Mr. H. Watson Smith, Yorkshire Branch; Mr. F. Mawson, Yorkshire Branch; Mr. W. T. Barrow, Doncaster Branch; Mr. S. J. Roseblade, North Western; Mr. R. F. Bull, North Western; Mr. W. E. Mangnall, North Western Branch; Mr. A. E. Ashworth, North Wales; Mr. C. D. Wilkinson, Midland Branch; Mr. E. R. Hudson, Midland Branch; Mr. L. C. Gunnell, Warwickshire Branch; Mr. W. G. Thompson, Warwickshire Branch; Major W. Roberts, South Wales Branch; Mr. H. J. Norton, South Wales Branch; Mr. E. F. Cope, Western District; Mr. T. B. Stanaway, Western District; Mr. W. Thomas, Western District; Mr. C. St. C. Saunders, General Secretary. Mr. E. Dinsdale Phillips, Editor, was also in attendance.

Letters of apology for absence were received from Messrs. C. Augustus Carlow, Past President; F. Anslow, Past President, Certification and Publications Committees; S. Walton-Brown, Past President, Certification Committee; W. M. Thornton, Past President, Examinations Committee; A. Anderson, Past President, Finance Committee; Dawson Thomas, Certification and Prizes Committees; D. S. Anderson, Lothians Branch; W. G. Gibb, West of Scotland Branch; R. G. Wilson, North of England Branch; A. R. Hill, Cumberland Branch; L. Fidler, North Wales Branch; F. A. Foster, Stoke Branch; J. W. Cartwright, Stoke Branch; and C. C. H. Smith, Kent Branch.

The Minutes of the General Council Meeting held on June 12th, 1931, having been distributed, were confirmed and signed by the Chairman.

Finance.

Statements were presented setting forth the position of the General, Deposit and Publications Accounts, an analysis of the Branch Funds at June 30th, 1931, the Subscriptions, Entrance Fees, and other items received during the same period, and also an analysis of the Membership on the same date.

Branches.

The Quarterly Statements of the Branches were brought before the meeting by the representatives.

The application of the Western District Sub-Branch to be raised to the status of a full Branch was carefully considered, and the representatives of the Sub-Branch explained the points upon which they made the application. Mr. Muirhead, on behalf of the Advisory Committee, stated that the Committee suggested that the Sub-Branch should confer fully with the South Wales Branch Executive, and obtain particulars regarding the opinion of the Members in the Sub-Branch District, and their wishes with regard to the section to which they should be attached and any other particulars, also that the area of the two Districts should be clearly defined. The representatives of the Sub-Branch undertook to obtain the necessary information, and it was resolved that this matter be considered again at the next General Council Meeting.

Examinations.

Mr. Fisher reported on behalf of the Examinations Committee, the report was adopted, principal items being to the following effect.

Service Examinations to be continued for another year.

The term "Mine" is used as meaning any underground working, and when the Candidate's experience is limited (that is to say he has no experience of coal mining) his Certificate should be endorsed to this effect.

It is recommended that the following should be added to Section (9) of the Rules governing Examinations. "Before presenting himself for the Honours Examination the Candidate must have obtained a First Class Ordinary Certificate."

The Committee consider that all application forms for Examination should be sent to the General Secretary at least one month before the Examination.

The Committee recommend that the Branches be asked to obtain information as to the number of Institutions who have adopted in any way the suggested Courses of the Association.

The dates for the next Examinations to be decided at the next Council Meeting so as to enable the Committee to consult the Chief Examiner.

Underground and Surface Lighting.

Mr. Stretton reported upon certain steps which were being taken outside the Association. Mr. Muirhead reported upon replies which had been received from

the Branches, and it transpired that although some of the Branches had given certain consideration to this matter, others, in consequence of the Summer vacation, had not been able to arrange for meetings to consider the subject. It was, therefore, agreed that the General Secretary should write the Mines Department asking for further time in which to draw, and present, a report; stating that the matter was receiving careful attention and that a report would be submitted as soon as possible.

Repair of Trailing Cables.

Mr. S. A. Simon reported on behalf of the Papers Committee that practically all the Branches approve of the suggested paper and demonstration, and recommend that the General Council, through the General Secretary, should ask the Cable Makers Association to provide a suitable paper and demonstration. It was considered that the demonstrations should not be confined to one type of cable or to one pattern of vulcaniser, and also that used cables be demonstrated with, not new ones. It was further suggested that the Mines Department might outline any points which they would like particularly stressed in connection with the demonstrations.

Annual General Meeting.

A letter was read from the West of Scotland Branch conveying an invitation to the Association to hold the Annual Convention in 1932 in Glasgow. The letter was received with gratification and the invitation was accepted with appreciation.

Faraday Centenary Celebrations.

The Chairman reported that he had attended the various functions as representing the Association.

Association Gold Medals.

The General Secretary reported that eight Members who hold Gold Medals of the Association had been provided with an attachment for wearing the same, as resolved at the last General Council Meeting, and this had been considered satisfactory by the recipients.

British Engineering Standards Association's Committees.

Mr. Stretton reported that he had attended several Meetings of the Committees, but there were no special items to which he wished to draw the attention of the General Council.

WEST OF SCOTLAND BRANCH.

Visit to the Mirrlees Watson Works.

On September 12th last the members of this Branch were privileged to inspect the Glasgow works of the Mirrlees Watson Co., Ltd.. They were shewn through all the departments including pattern shop, foundry, laboratory, machine shops, and erecting shops. The machinery on view in the pump erecting shop comprised de-aerators, condensers, and a large variety of pumps in various stages of completion. High lift or multi-stage pumps are manufactured for water works. The largest of these had a capacity of 1000 gallons per minute against a head of 600 feet, and similar pumps, with fewer stages were suitable for a head of 300 feet. Multi-stage pumps of this type, suitable for boiler feed purposes, were also seen. This type of centrifugal pump is used for de-watering mines.

Exceptional interest was shewn in the large number of "Chokeless" pumps in various stages of construction. These pumps are capable of dealing with liquids carrying pieces of solid material, which will pass through the inlet, up to six inches; they are used chiefly for pumping sewage and like duties where an ordinary centrifugal pump would be unsatisfactory. A large number of these pumps have been supplied to sugar factories for pumping unscreened juice containing cane fibre. They have also been supplied to power stations for clearing debris such as pebbles, sand, etc., from the intake culverts, and to collieries for pumping coke breeze and slurry.

One of the smaller sizes of these pumps was shewn in operation in conjunction with an apparatus for demonstrating the method of evenly distributing unstrained juice over crushed cane in sugar mill carriers. Nuts, bolts, etc., were passed through the pump to demonstrate its capabilities.

A large vertical spindle sewage pump, with 27 ins. discharge branch—one of three pumps supplied to the London County Council for pumping sewage at Deptford Pumping Station—was being erected. This pump has a capacity of 72 tons of sewage per minute, against a 24 ft. head. Two similar pumps had already been despatched: one of the same capacity, whilst the third had a 33 ins. discharge branch, and a capacity of 108 tons per minute.

A variety of split-casing pumps were being built. Two of these were shewn in operation on the test bed: one being a horizontal spindle pump and the other a vertical spindle pump. A small petrol engine driven pumping set in operation evoked considerable interest.

Several steam ejector air pumps were also seen. These are used for producing the high vacuum required in the condensing plants of large power units in electricity generating stations, and have superseded reciprocating pumps for this class of work. Several reciprocating air pumps were under construction for use in sugar factories.

A dynamic balancing machine, instead of static balancing, is used for balancing the impellers. This method ensures smooth running and little load being set up on the pump bearings, and is essential for high speed running.

In the erecting shops a number of parts for cane sugar factories were being built, including a cane crushing mill, a quadruple effect evaporator for concentrating the cane juice to syrup, and a vacuum pan for crystallising the syrup.

In the machine shop, in which all the machining of parts is carried out, are a large variety of modern lathes, planing, drilling, milling and slotting machines; all pieces are finished to gauges so that replace parts may be furnished for machinery which is shipped abroad.

As an adjunct to the foundry, is a fully equipped testing and chemical laboratory, where a close control is kept upon the quality of the product and the nature of the sand used by the moulders.

About sixty members of the Branch took part in the visit. They were received by Mr. W. A. Dexter, Director, and following the visit the members were entertained to tea.

Mr. A. Dixon, Branch President, on behalf of those present, extended the best thanks to the Mirrlees Watson Co. for the most interesting and useful visit.

Mr. Dexter suitably replied, and stated that at a later date, when some of their larger orders were nearer completion, the members would be welcome to pay another visit.

LOTHIANS BRANCH.

Visit to the Grangemouth Refinery of Scottish Oils, Limited.

On September 27th last some sixty members of the Lothians Branch were privileged to inspect the oil refinery at Grangemouth. The plant is one of the most up-to-date in the country and it was not surprising that members were quick to take advantage of the invitation. The tour of inspection began at the jetty which in truth is the real starting place in the scheme of things at Grangemouth. Here, large tank steamers arrive with crude oil from the prolific Persian fields, and depart with the finished refined products for home ports and the Continent. Connecting the jetty and tank area or "farm" are a number of pipes; twelve inch mains for the transfer of crude oil from ship to storage tanks, and others of ten inches for the transfer of finished products from tank farm to ship. While at the jetty the visitors were enabled to inspect also the buildings erected for the accommodation of the ships' officers and crews.

Proceeding to the pump-house, the party inspected the large number of pumps for the transfer of finished products from stock tanks to jetty and filling shed and of crude oil from storage to the topping plant; also the pump for sending forward the necessary crude oil to the Uphall Refinery sixteen miles distant. The pumps in No. 1 house range in capacity from 175 g.p.m. to 1400 g.p.m. and all are of the centrifugal type, directly coupled to alternating current motors running at 1440 r.p.m. It was pointed out that all the sludge which separates out from the crude oil on standing at the tank farm is transferred at intervals to a recovery plant where the oil is extracted in steam-coil heated cylindrical tanks.

The introduction to the refining process proper was made at the topping bench where the crude oil arrives for its first distillation. Described briefly, the oil passes through a counter-current heat exchanger, the exchange being made with hot fuel oil passing away from the last still in the battery, then through a pipe still. The oil being now at an extremely high temperature is flashed into a fractionating tower, from the top of which is taken off the lightest vapours and these are subsequently condensed in a water-cooled coil and collected for further chemical treatment. The heavier portion of the crude oil from the bottom of the fractionating tower is led to the first still of the series, and thence to the second, third and fourth. These stills, five in number (four always in commission), measure 36 ft. long by 21 ft. diameter, and heating is accomplished by fuel oil. From each still an overhead pipe carries the vapours to the condensing system consisting of dephlegmator, soda washing tower, and water-cooled condenser. The function of the soda-washing tower is to remove sulphuretted hydrogen and the like which would otherwise cause severe corrosion of lines and metalwork in general. The lightest distillate condensing in the water-cooled condenser is run to a sight-box in the tail-house, and thence by a down line to the receiving tanks.

This once-run distillate is then transferred to a second bench of stills receiving en route a chemical treatment with caustic soda. These stills are heated by steam alone and adjusted so that the products obtained are motor spirit and kerosene conforming to specification. The motor spirit along with the light spirit obtained at the pipe still fractionating tower already described is then treated chemically with sodium hypochlorite. This hypochlorite is made on the spot from chlorine and caustic soda, the latter chemical being likewise manufactured from lime and soda-ash and stored in the form of a ten per cent. solution to be used directly in the treatment of the oils and for sodium hypochlorite manufacture.

The motor spirit is treated in a large washery using the Holley-Mott System, the spirit receiving its chemical agent in counter-current fashion, and the plant consists of a series of vessels provided with mechanical agitators in which mixing and separating are performed alternatively and automatically.

The kerosene obtained as bottoms from the steam stills, along with that collected as a heavy fraction at the topping bench, is given a caustic soda wash to remove sulphuretted hydrogen, dehydrated by passing through a column of bauxite, and led to the sulphur dioxide plant. Here the crude kerosene is brought into contact with liquid sulphur dioxide at a low temperature, and this reagent extracts aromatic bodies which, when removed from the kerosene, greatly enhances its burning qualities but which, strange to say, when added to the motor spirit, greatly improves this product from the anti-knock standpoint which is the essential criterion in judging a motor spirit at the present time. The fit-up of this SO_2 plant was favourably commented on and all agreed that it was a magnificent piece of engineering work.

Crossing over to the bauxite plant it was explained to the party that this earth had to be roasted in order that it might be activated to the degree necessary for decolorising and desulphurising the product, and the crushing plant, rotary incinerators, and recovery system for this process were scrutinised with particular interest.

Passing thence to the oil cracking plant, it was explained that the two units installed dealt with the major portion of the heavy oil from the topping bench, and by submitting this heavy oil to the high temperature and moderate pressure in the plant it was split up into fractions of lower boiling point, and thus provided by this ingenious method more petrol for the ever-increasing demands of motorists. In the control-room of the plant, the instrument boards acted as a magnet to the majority of the party, and after an explanation and demonstration of how all the tell-tale recorders and meters made the unit so easy to handle one came away realising more fully what applied science really means to industry in the present century.

It was natural that the power plant should also evoke the great interest of the visitors and, starting with the steam boilers, it was noticed that these were of the straight tube, six drum type, each with a chain-grate stoker complete with forced-draught fans and operating gear, driven by electric motor situated in front of the fuel hopper. The coal was handled by hydraulic tipping gear, bucket elevator, and scraper conveyor, and delivered to the boiler storage hoppers. Steam is generated at 200 lbs. pressure and 200 degs.F. superheat for use in the turbines and also for process work. A check upon the composition of the flue gas is maintained by CO_2 recorder, and this along with draught-gauges guides

the boiler-house attendant in adjusting conditions of combustion so as to obtain maximum efficiency.

The turbo-alternators and the auxiliaries are housed in a steel-framed brick building of two storeys situated alongside the boiler-plant. The lower floor accommodates the condensers with pumps, auxiliary switch gear, etc., while on the upper floor are situated two turbo-alternator sets, main switch gear and instruments, motor generator, two electrically-driven air compressors and one auxiliary steam driven direct current generator. The alternators are twin sets, each of 1000 k.w. capacity generating three-phase a.c. 50 cycles at 500 volts. Steam at 200 lbs. pressure is admitted to the turbines, and after passing through seven impulse stages exhausts to condensers on the lower floor. The turbine speed is 5500 r.p.m. which, through helical gearing, is reduced to 750 r.p.m. at the alternator end. The turbines are arranged to pass out steam up to 10,000 lbs. per hour between the first and second stages at a pressure of 35 lbs. to 40 lbs. per sq. inch.

The main switchboard consists of twelve panels of the ironclad type. The usual protection gear and instruments are fitted, and a separate panel carries an automatic voltage regulator which can be used with either alternator. An ironclad switchboard is also provided for the lighting system, the supply being taken either from a motor generator set or a steam-driven set giving direct current at 230 volts.

The electrical plant generally consists of 180 electric motors with a total horse power of 4000. There are also 1600 electric lamps and approximately 10 miles of paper-insulated lead-covered and double-wire armoured cables. The whole of the switchgear throughout the works, the enormous number of panels of which was commented upon by many of the party, was, with the exception of the power station gear, all supplied by George Ellison Ltd. The power station main gear was principally of Reyrolle manufacture.

On the way back to the main offices the party passed through the workshops where, in one building, are the engineers' workshop, store, electricians' shop, blacksmiths' shop, and joiners' shop.

Lastly a visit was paid to the very up-to-date works laboratory where finished products were exhibited, and their properties explained by the chemical staff. It was noticed that much of the laboratory apparatus was electric, thus minimising fire risk. Great precautions are in fact taken throughout the whole works against fire, and the introduction of the "thermos flask" or fireless type of locomotive is a means to this end.

What impressed everyone on the visit was the neat and methodical layout of the various units and the cleanliness of the place; it was rather difficult to realise that this undertaking was putting through approximately 300,000 gallons per day of crude oil.

The description given here is all too brief and cannot adequately deal with all the multifarious processes which go on here from day to day, but it will serve to shew to some extent what actually is being done. Those members who were not present on this occasion will be able to judge what strides have been made in the art of petroleum refining since the last visit of the Association to these works several years ago.

After the tour the visitors were entertained to tea in the Works Office. Mr. Annan, the works manager, welcomed the party on behalf of the Directors of Scottish Oils and expressed his own pleasure at having the members of the Lothians Branch at Grangemouth on this occasion.

Mr. Russell on behalf of the President of the Branch, Mr. Webster, who was unable through illness to be present, thanked the Directors of Scottish Oils for their kindness to the members of the Association. He expressed their cordial appreciation of the splendid way in which Mr. Annan and his staff had entertained them.

WARWICKSHIRE & SOUTH STAFFS. BRANCH.

Visit to Waterworks Pumping Stations.

On June 27th last the Branch, at the invitation of Mr. Fred J. Dixon, Engineer-in-Chief of the South Staffordshire Waterworks Co., visited the Company's Prestwood and Kinver Pumping Stations. A party of sixty availed themselves of the opportunity and of the very favourable weather which made the visit to these excellently equipped stations surrounded by magnificent scenery, both interesting and enjoyable. After inspecting the works the members took tea in Kinver, and Mr. L. C. Gunnell, the Branch President, made cordial references to the kindness of Mr. Dixon in again giving the Branch the opportunity of following the Company's developments in electrical practice. Mr. W. H. Fellows, responding, expressed the regret of Mr. Dixon at being unable to be present and assured the Branch of his interest in the work of the Association and the pleasure it gave him to be of help. On his own behalf Mr. Fellows said that he had taken pleasure in describing their equipment and was happy to know that the event had been so successful and enjoyable.

The Prestwood Plant.

The main building of the Prestwood pumping station is the engine house, 60 ft. by 32 ft., which is lofty and is well lighted by large windows at the sides and ends, and by a skylight. The height of the engine house from floor level to the top of the crane gantry is 14 ft. 8 ins.: the height to the underside of the tie bar is 22 ft., and the total height of the building from basement floor level to the underside of the tie bar 34 ft. 6 ins. The accommodation on engine house floor level includes also office, stores, switch room, low tension cubicle room, and high tension cubicle room, whilst in the basement are pump rooms, transformer house, workshop, heating chamber and lavatories. A large motor garage is a separate building.

The main pumping plant consists of a borehole pump and a force pump in series for each of two boreholes. Both pumps are of the centrifugal type, and are driven by a common vertical shaft, connected through a flexible coupling to a vertical spindle induction motor. Each motor is provided with a speed-regulating set, designed for power factor correction and sub-synchronous speed regulation. The power supply is three-phase, 50 periods, 11,000 volts, and this is transformed down to a pressure of 440 volts by means of two 1200 k.v.a. transformers, each of which is of sufficient capacity to deal with both pumping units running at full load.

The pumps were specified to fulfil the following duties: Each unit, when running singly, was to be capable of pumping a net quantity of 2084 gallons per minute (three million gallons per day) from any depth down to 150 ft. below basement level at the station, and delivering same through approximately seven miles of 24 ins. internal diameter steel delivery main, against a static head of 563 ft. above basement level at the

station, and an estimated friction head of 20 ft., making a total inclusive head of 733 ft. The two units, when pumping simultaneously in parallel, were to be capable of pumping twice the above quantity of water under the same conditions, except that the estimated friction head was to be 70 ft., making a total inclusive head of 783 ft.

In addition each motor and all parts of the borehole pumps were to be suitable for dealing with the extra load involved in the event of it being necessary, at a later date, to lower the borehole pumps to pump from a depth of 200 ft. below basement level, due to a permanent fall of the water level in the boreholes. All water taken from the borehole pump delivery mains and used for water lubricating, cooling, or other purposes, is discharged to waste, and only the actual water pumped to the reservoir, as measured by the meter fixed in the delivery main, was taken into account when determining the output and efficiency of the plant.

The borehole pump has seven stages, and is provided with a 14 ins. bore steel suction pipe, bronze fitted foot valve, and perforated copper strainer. The impellers are of the single-inlet type, made of bronze and keyed to the shaft. The guide wheels are of bronze and the pump casing of cast iron.

The force pump is of the four-stage type, the casing and guide passages being of cast iron: the impellers are of the single-inlet type, made of bronze, the guide wheels are also of bronze and the neck rings of cast iron. The vertical spindle induction motor is coupled to the pump shaft through a shrouded flexible coupling of the rubber buffer type.

The power for the station is supplied by the Shropshire, Worcestershire, and Staffordshire Electric Power Company, a dual supply being available, one by an overhead line direct from the power station at Stourport, and the other from Amblecote sub-station by an underground cable. Under normal conditions, the load is carried by the overhead line to the switchgear at the pumping station. In the event of a failure on this source, the sub-station can switch on the supply from Dudley or Smethwick power station. If a failure occurs, the alternative supply can usually be brought into use within ten minutes. There are five cubicles in the high tension control room at the pumping station, two containing the isolating links and switches for the dual supply which feeds to busbars. The centre cubicle is for the metering equipment, and is fitted with a recording voltmeter, two k.v.a. hour and two k.w. hour integrating type meters with maximum demand indicators, which are connected so that one k.v.a. hour and one k.w. hour meter are working on one set of current and pressure transformers. The mean reading of the two sets of meters is taken for purposes of payment. The remaining cubicles control the supply to the two 1200 k.v.a. transformers. From these transformers the low tension supply is carried by bare copper conductors on porcelain insulators, supported by racks fixed to the ceiling of the transformer room, to the low tension switchgear.

The main low tension switchboard consists of five panels; the two end panels carry the switchgear for the main motors, and the two intermediate panels control the low tension side of the 1200 k.v.a. transformers. The centre panel carries the switchgear for the overhead crane and lighting transformers.

The two main transformers are of the three-phase oil-immersed, indoor type with air cooling radiators. They are mounted on rollers and have spring supports for the windings. The continuous output of each transformer is 1200 k.v.a. at 50 cycles, and they have an efficiency of over 97 per cent. on full load. The star point of the secondary of each transformer is taken through an earthing cubicle, and earthed direct to two plates buried about 9 ft. deep and 25 ft. apart, outside the building.

The main motor for each pumping unit is of the vertical shaft induction type, of drip-proof construction, with wound rotor supported by a self-oiled, water-cooled thrust bearing fitted in the top cover. Each motor has an output of 670 h.p. at 725 r.p.m., with a three-phase supply at 440 volts 50 cycles, and a temperature rise of 40 degs. C.

The speed regulation of the motors is controlled by a Scherbius set, and when this is in operation, each motor can develop a normal continuous output of 725 brake-horse-power, with a temperature rise not exceeding 40 degs. C. A continuous overload of 75 brake-horse-power, giving an output of 800 brake-horse-power, can be obtained with a temperature rise not exceeding 50 degs. C.

The principles of the Scherbius speed-regulating set is as follows. If the speed of the main motor were reduced by inserting a resistance in the rotor circuit, the efficiency of the machine would be reduced a corresponding amount, the loss being mainly represented by a rise in temperature of the resistance. If an equal reduction in speed is obtained on the Scherbius principle, however, the overall efficiency falls only about 1 to 2½ per cent., and the greater the reduction in speed, the greater is the energy saved. The regulating set, which controls the main motor speed from about 725 r.p.m. to 610 r.p.m., consists of a three-phase commutator machine, developing 100 k.v.a. at 145 volts, with an armature similar to that of an ordinary direct current machine. Its stator is wound with three distinct windings, consisting of compensating field, interpole field, and exciting field windings, and is direct coupled to a 440 volt, 50 k.w., 50 cycle slipring induction motor, running at 1500 r.p.m.

The function of the regulating set is to provide a source of adjustable voltage which may be imposed on the rotor windings of the main motor in such a way as to adjust the speed economically, independently of the load. The commutator machine provides this voltage at rotor frequency, and it is introduced into the rotor windings to oppose the slip voltage. The rotor voltage being in direct proportion to the slip, the speed of the rotor will adjust itself to such a value that the rotor voltage exceeds the opposing voltage from the commutating machine by an amount equal to that necessary to send through the impedance of the circuit sufficient current to develop the required torque. The exciting winding of the commutator machine is fed through a resistance by a three-phase auto-transformer, provided with a number of tappings and connected directly across the main motor sliprings. The tappings can be varied by a small regulating switch operated from the control desk, thus providing the means of regulating the opposing voltage from the commutator machine so that the speed of the main motors can thus be adjusted practically independently of the load.

As the slipring pressure feeds the compensating and exciting field windings, the current in the resistance and excitation circuit is approximately proportional to the slip, while the current in the compensating winding is constant, because the inductive resistance of the windings is proportional to the slip. The resulting excitation field of the commutator machine depends on the sum of these two excitation currents, therefore the armature voltage of the machine is composed of two parts, one proportional to the slipring pressure, and the other a

constant component. The resistance in the exciting field winding is so adjusted that the component of the armature voltage is smaller and opposed to the proportional slipring voltage, consequently the resulting voltage is only a fraction of that on the slipring.

The rotor current and torque of the main motor for a given slip would be smaller than without the commutator machine, if this slip were not further augmented by means of the interpole field winding, carrying the full armature current, which induces a further voltage proportional to the rotor current but opposite to it. The voltage produced by the compensating field winding lags 90 degs. behind the voltage of the resistance and exciting field winding, and affects the phase advance or power factor correction. Thus, the commutator machine runs as a generator, so far as it is called upon to make up the magnetisation losses in the rotor circuit; whereas it runs as a motor in taking up the slip energy of the main motor. Although the regulating set is, at present, only required for reducing the speed of the main motor from 725 r.p.m. to 610 r.p.m., it can, by the addition of a small frequency changer, increase the speed above synchronism to about 825 r.p.m. and, under those conditions, the commutating machine would run as a generator driven by the 50 k.w. induction motor.

The starting up of a pumping set is carried out by switching on the supply to the main motor, which is run up to full speed by means of a water starter. The Scherbius speed regulating set is then also run up to speed by means of its starting motor, which carries a built-on stator switch and rotor starter that automatically short circuits the rotor and lifts the brush gear off the sliprings when in the full-on position. The commutator machine is now switched on to the sliprings of the main motor by means of a change-over switch, and, by adjusting the tapping switch which controls the excitation field of the commutating machine, the main motor speed can be reduced to suit the working conditions.

The starting is practically fool proof, as all circuits are interlocked, and it is necessary to carry out all the operations in their proper sequence. This interlocking is designed to prevent switching on the power to the main motor when the water starter and the regulating machine starter are not in the starter positions, and to prevent switching over the rotor circuit from the water starter on to the commutating machine before it has been run up to full speed.

The Kinver Plant.

The Kinver pumping station is remote supervisory controlled from the Prestwood pumping station. The plant consists of two Mather & Platt eight stage, high lift, turbine pumps, each capable of delivering 70 gallons per minute against a total head of 400 feet when driven at a speed of 1440 r.p.m. Each pump is direct coupled by a flexible coupling of the sliding type to a standard Mather & Platt induction motor of 17 B.h.p. and mounted on a box pattern bed with a trough cast all round to prevent drippings from reaching the floor.

Each motor is controlled by an automatic contactor type rotor starter panel fitted in an iron case of the pillar type with hinged glazed front doors. The starter controller is of the inching pattern comprising a series of double pole electrically operated air brake contactors controlled by a solenoid type master switch with eddy current retarder to ensure correct starting. The rotor resistance is of the three-legged, air-cooled, pattern mounted in the pillar. The panel is fitted with a small switch which can be set at off, hand control, or automatic positions, and operates in the circuit controlling the triple pole contactor, and when in the automatic position the panel is controlled by the water indicating level apparatus which is a special feature of interest and a departure from the usual type embodying many new principles.

The automatic control system consists of a transmitter actuated mechanically by means of a float which transmits the movement electrically to the indicating, recording, and control instruments by means of two wires rented from the Post Office. The principle underlying the system is the regulation by the variations of water level in the reservoir of an electric current which passes through the transmitter and receiving instruments. The regulation is such that a definite current corresponds to every stage of the originating movement quite independently of the voltage or resistance of the wires in the circuit.

The system does not operate on the step-by-step principle and the receiving instruments cannot get out of step with the transmitter; in the event of a wire between the instruments breaking or a failure of the supply, the apparatus returns automatically to normal working without loss of accuracy when the line is repaired or the power supply resumed.

The transmitter consists of a cord drum turned by means of the rising and falling of the float which moves a pointer, to which are attached two contacts. Floating between these contacts is an electrical control pointer, so that when a movement of the pointer takes place the control pointer comes into contact with one of the two contacts and completes the circuit of one of two field coils of the control motor.

Energising the field coil of the control motor at the same time releases a brake which normally prevents the armature from revolving. The Armature turns and by means of worm gearing moves the contactor arm over the control rheostat. The direction in which the contactor arm is moved depends upon which field coil has been energised by the contact touched by the control pointer. As the contactor arm moves over the rheostat the current passing through the receiving instruments and moving coil controlling the control pointer is altered, and this change will continue until the control pointer reaches a position at which it floats freely between the contacts carried on the pointer controlled by the float. When this position is reached the field circuit is broken and the armature is stopped instantly by a releasing of the brake.

The electrical supply operating the transmitter is obtained from a 50 volt battery installed in the small building housing the transmitter and float gear at the reservoir, and receives its charge from a rectifier installed in the pumping station. A current of about 3 to 5 milliamps. passes along one of the Post Office lines through the battery back to the rectifier by an earth return, thus keeping the battery fully charged. The function of the battery is to overcome the voltage drop when the small motor in the transmitter comes into operation and to provide an efficient supply to work all the instruments of the water level apparatus in the event of a failure of the power supply at the pumping station.

The current from the transmitter is conveyed along a Post Office line to the pumping station where it passes through the level indicator and pump control relay. It is then taken by a Post Office line to the supervisory control station at Prestwood where it passes through the level indicator, recorder, and alarm relay, returning

by a Post Office line to the pumping station and back to the transmitter by the earth return.

The receiving instruments are milli-ammeters calibrated to read in feet, and the recorders are scaled on a 6 inch chart with a speed of one inch per hour, each chart lasting 30 days. The syphon pens and ink reservoir run six months without attention.

The pump control relay is of special design and consists of a milli-ammeter with contacts operating a mercury tube switch which opens and closes the circuit controlling the starting panel. In addition to the water levels being conveyed to the supervisory station, the readings of the ammeters on the panel are also under constant observation and recorded. The attendant is warned by an alarm if the power supply fails and can stop and start the plant by an emergency switch if any abnormal condition arises.

A current transformer is in circuit with one of the leads to the pump motors, the secondary circuit being taken to a transmitter similar to the water level transmitter except that the pointer, to which is attached the two contacts, is moved by an ammeter movement in place of the rising and falling of a float. This transmitter received its supply direct from the rectifier at 110 volts, the current passing from the transmitter along a Post Office line to the supervisory station through the receiving instruments and emergency switch, returning by a Post Office line to the transmitter.

When the motors are out of commission the pointers of the receiving instruments at the supervisory station will be on the "O" ampere reading, but in the event of a power failure the pointers fall back and indicate "Supply failure", the attendant being warned at the same time by the alarm relay closing the local battery circuit an dringing a bell.

The emergency switch opens and closes the circuit from the ammeter transmitter. When the circuit is broken the small motor in the transmitter moves the contactor arm over the control rheostat and opens a contact in the circuit controlling the starting panel and reversing the operation when the ammeter circuit is closed.

The two pumps draw water from a well 8 feet diameter and 16 feet deep, from the bottom of which an 11 inch diameter borehole has been taken into the new red sandstone to a depth of 120 feet. The borehole is lined to a depth of 100 feet with steel tubes.

DONCASTER SUB-BRANCH.

Visit to Callender's Cable Works.

Forty-two members and friends of the Doncaster Sub-Branch paid a visit on July 20th last to the Anchor Cable Works, Leigh, of Messrs. Callender's Cable and Construction Co., Ltd., and were given the privilege of seeing rubber insulated cables during various stages of manufacture. The inspection accompanied with expert commentary made each operation clear and understandable.

Mr. T. H. Williams (Branch President) thanking Messrs. Callenders for the generous programme provided said that he had, personally, experienced little trouble in connection with cables with the exception of trailing cables. He thought that with trailing cables an improvement could be made in the manner of Ferflex braiding.

Mr. J. BOWYER (Works Manager, Anchor Works) in reply said that he welcomed any comment or suggestion which would help to complete satisfaction between manufacturer and customer. Regarding trailing cables he was pleased to say that Messrs. Callenders were now producing an improved cable which was free from the weaknesses of the older cables.

A sample piece of the new cable after being subjected to a severe flexing test was passed around for inspection. The cable shewed no signs of "distress" and members were agreed that it would be their close interest to note its qualities under actual pit service.

The Doncaster Sub-Branch at Callender's Cable Works.

SOUTH WALES BRANCH.

Presidential Address.

Transportation of Coal *versus* the Transmission of Electricity.

MAJOR W. ROBERTS.

(*Meeting held 17th October*, 1931.)

An Engineer has somewhere been described as a man who can do a job of work either better, quicker, or cheaper by his science of engineering than the work can be done by manual labour. Judged by this standard, are we yet entitled to call ourselves Engineers in regard to the two commodities with which we are all familiar—Coal and Electricity—based upon the comparison set out in the title of this address.

In 1927 in his Paper dealing with the Electricity Supply Act of 1926 and the Mining Industry, our Association President, Major David, discussed this question briefly, and dismissed it in a few lines, the advantage then being undoubtedly in favour of the carriage of coal. He gave no detailed workings, but the unit cost over a distance of 50 miles was—

Coal—0.05 pence
Electricity—0.08 pence.

In 1928 during the discussion on the location of the new Battersea Power Station, evidence was given by

the London Power Co. that a nett saving of 6s. per ton in freight would be necessary to justify the station being installed 20 miles down stream. This figure, however, included for the supply cables being taken underground, and undoubtedly with overhead lines a much lower figure would have turned the scale in favour of generation remote from the load centre.

Coal has been carried in open trucks for the past 70 years in much the same manner as to-day, except for the one factor that the size of the container has been increased so as to reduce the cost of handling and dead freight charges. The transmission of electricity on a large scale is comparatively new, at least in this country, and it is of interest to see if it is not a more economical method of doing work than the old-fashioned one devised so many years ago.

The problem is not an academic one, as it is of vital importance to the location of main load stations. Some years ago our President criticised the composition of the Central Electricity Board upon which Municipal Engineers and particularly Metropolitans predominated at the expense of any representative from the collieries, or the larger users, and it will be interesting to know whether this bias has resulted in a less economic location of the stations than would have occurred had the views of the users been more clearly considered.

I set out below the details of my investigation, but will say right away that the conclusions I have reached indicate that a good case can be made out for electrical transmission, and I believe a big reduction in the cost of electrical plant and equipment in the past few years is the reason why a different answer may be found to-day to this problem than what was expected three years ago.

In order to get the problem on a concrete basis for discussion, I have assumed a hypothetical station with a plant capacity of 100,000 k.v.a., and a load factor of 40%. The two cases I have examined are whether it is more economical to install this station at Cardiff in the centre of the load, and bring coal to it from the neighbouring valleys (the average distance I have allowed for being 20 miles) or whether it is not better to put this station, say, at Aberaman, where it is surrounded by collieries, and transmit the equivalent load in the form of electrical energy. I am aware that the final choice of a site depends upon other factors of which water is the most important, some 500/600 tons of water being required for every ton of coal burned, but I am assuming that this is common to both sites.

A predecessor of mine in this Chair, Mr. T. S. Thomas, dealt with this problem in part, but in a different way, i.e., one of coupling up towns and collieries electrically to improve the load factor of both, but in order to get a strict comparison, I am going to assume that all the posible variables at the stations at either end can be eliminated. Furthermore, I am assuming that the costs of building, equipping and running a station at both places are the same, and that the same thermal efficiency can be obtained in both places, so that all questions relating to the efficiency of the stations can be ignored, and the problem resolves itself down to one of transmission only so far as electricity is concerned. Although it may be considered unnecessary for such a short distance, I am satisfied that for a load of this size, it is more economical to work at the grid pressure of 132,000 volts, and all the figures have been based upon apparatus at this pressure.

Plant Required.

Step up and step down transformers with the necessary switchgear will be wanted at each end of the line, and these with the transmission line are to be capable of dealing with 100,000 k.v.a. Each equipment will comprise two 60,000 k.v.a. three-phase, 50 cycle oil-cooled, weather-proof outdoor type transformers, ratio 33,000 volts to 132,000 volts complete with on-load tap changing equipment. At the other end two similar transformers, but stepping down will be required. The transformers will be in accordance with the usual C.E.B. specification, and the price for these, delivered and erected, at 5s. 3d. per k.v.a. would be £64,000 for the two sets. The cost of the substations including all necessary switchgear, other than the transformers, is £30,000 at each end, giving a total capital cost of £60,000.

The transmission line to operate at 0.9 P.F. would comprise 20 miles of 0.175 square inch equivalent steel core aluminium double circuit 132,000 volt overhead line with a 0.0648 square inch equivalent steel core aluminium earth wire, erected on wide base lattice steel towers at 900 feet spans. Intermediate tower positions would have suspension insulators consisting of nine 10 ins. diameter cap and pin units in series, and at "make-off" and "terminal" positions, the strain insulators would consist of eight 12 ins. diameter cap and pin units in series. The towers would be of the self-supporting pattern, galvanised and despatched piece-small and bolted together on site. The foundations would vary according to the type of country, and would be of either of the three types, namely, earth, concrete block, or rock. The cost inclusive of all necessary fittings, earth pipes, concrete, etc., would be £2,600 per mile, giving a total capital cost of £52,000.

I have allowed for interest on capital outlay at the rate of 5%, and this is on the right side, as it is possible for the C.E.B. to borrow money at slightly less. The loan period for the different classes of apparatus vary slightly, the transformers and switchgear being 20 years, the overhead lines 25 years, and the buildings to accommodate transformers and switchgear 30 years. I have made enquiries from Manufacturers of this gear, and am quite satisfied that present-day apparatus can be made which will outlast the loan periods mentioned above, provided due care is given to maintenance. To be on the safe side, however, I have taken the lower figure of 20 years for all of the gear and, based upon this life, have allowed a sinking fund of 3% making a total standing charge for capital expended of 8%.

In addition I have allowed a figure of 2½% maintenance on all three items, switchgear, transformers and overhead line, while in addition I have added 1% to the cost of the overhead line to cover the cost of way leaves, compensation and local rating. These latter while they are an uncertain quantity are not likely to be high if the line is the property of the C.E.B., and not a private enterprise.

On this basis of 10½% per annum for transformers and switchgear, and 11½% for the line, the total charges come out at £19,000 per annum. Assuming a load factor of 40%, the total units per annum will be 350,000,000, and the standing charge, therefore, comes out at 0.013 pence per unit, thus :

$$\frac{19{,}000 \times 240}{350{,}000{,}000} = .013\text{d.}$$

The total being made up by

Transformers	.0046
Switchgear	.0043
Transmission Line	.0041
	.0130d.

Table I sets out these figures in tabular form.

TABLE I.

Apparatus	Capital Cost	Interest 5%	Allowances Sinking Fund 3%	Maintenance 2½%	Way Leaves 1%	Total
Transformers	£64,000	3200	1920	1600	—	6720
Switchgear	£60,000	3000	1800	1500	—	6300
Transmission Line	£52,000	2600	1560	1300	520	5980
						£19,000

Losses.

An estimate of the no-load losses on each bank of transformers is ... ... 330 kilowatts
The copper loss at 40% load factor being ... ... 180 „

510 „

The total losses, therefore on the two sets come to ... ... 1020 „
Dealing next with the line losses, the approximate resistance per mile of conductor is 0.26 ohms or 0.13 ohms per mile for the double line, giving a total resistance for the 20 miles of 2.6 ohms. The average current with a load factor of 40% works out at 225 amps., giving a power loss per phase of 130 kilowatts or, for the three double lines, a total of 390 „

Making a grand total of ... ... 1410 „

of which copper loss is 750 k.w. (53% of the total) and iron losses 660 k.w. The approximate total power loss in the lines and the transformers is therefore 1410 kilowatts or 33,840 kilowatt-hours per day or 12,351600 kilowatt-hours per annum being approximately 3½% of the units transmitted. The works cost of generating electrical energy in a station of this size should not be more than 0.2 pence per unit, and the energy wasted in the lines and transformers involves an addition of 3½% of 0.2, say 0.007 pence per unit. The total cost of conveying electric energy between these two places is therefore 0.13 plus 0.007, i.e. a total of 0.02 pence per unit.

Coal.

I have had great difficulty in getting an accurate figure for the conveyance of coal, because I find that rates, even for similar distances, vary greatly in different districts according to whether competition existed or not prior to the railway amalgamation. I have obtained figures from eight different sources, the distances being comparable with the figure under discussion, and a fair average for all these appears to be 2d. per ton mile. Wagon hire on top of this involves an additional charge of 7d. per ton making a total cost of 3s. 11d. per ton for the 20 mile journey. This comes out $\frac{47}{2240}$ to 0.21 pence per lb., and assuming 1.2 lbs. of fuel per unit, the railway cost for the fuel haulage is 0.0252 pence per kilowatt hour.

It will thus be seen that on this comparison I make a claim for an advantage of 20% in favour of electrical transmission.

I should like to deal briefly with the effect upon these figures that varying conditions would have, the three variables being distance, coal consumption, and load factor.

Distance.

At any distance beyond 20 miles, the advantage is greatly in favour of electricity, because the reduction in freight for coal is not very great, being a mere fraction for a reduction in the truck hire charges, the actual freight per ton being proportional to the distance, exact figures upon which my comparisons are based being as follows:—

	Freight.	Truck Hire	Total
20 miles	3s. 4d.	0s. 7d.	3s. 11d.
30 miles	5s. 0d.	0s. 9d.	5s. 9d.
40 miles	6s. 8d.	0s. 10d.	7s. 6d.
50 miles	8s. 4d.	1s. 0d.	9s. 4d.

On the other hand the cost of electrical transmission does not go up anything like in direct proportion. The transformers and switchgear cost the same, and the only addition is the capital charge on the extra cost of the transmission line itself, and the increased losses in this line. Table II. sets out clearly the relative figures for distances of from 20 miles to 50 miles, and it will be seen that the initial advantage of 20% in favour of electricity is increased to 29% at a distance of 50 miles, when the relative costs are 0.0427d. and 0.06d. respectively. The diagram, Fig. 1, shews these figures in the form of a graph.

Fuel Consumption.

The next variable is fuel consumption, and this, of course, is greatly in favour of Coal, because with any improved efficiency in boiler house conditions, the quantity of Coal required varies in direct proportion. The only saving from the electrical point of view is the reduced value of the losses.

Table III. sets out the costs at varying values of coal consumption per kilowatt hour from 1.2 lbs. down to 0.9 lbs., and it will be seen that at this latter figure the costs are very nearly identical. At anything below this, the figures would favour the transportation of coal, but the rate of progress in this direction has slackened off so much in the last few years that I do not think a general figure of much below 1 lb. of coal

TABLE II.—TABLE OF VARYING DISTANCES.

Miles.	Electricity.	Coal
20	0.02d.	0.0252d.
30	0.0276d.	0.0368d.
40	0.0351d.	0.0484d.
50	0.0427d.	0.06d.

TABLE III.

TABLE OF VARYING COAL CONSUMPTIONS.

Lbs. of Coal per kilowatt hour.	Electrical Costs.	Rail Costs.
1.2	0.020d.	0.0252d.
1.1	0.0194d.	0.023d.
1.0	0.0189d.	0.021d.
0.9	0.0183d.	0.0189d.

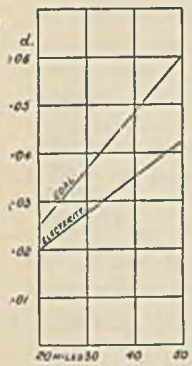

Fig. 1.

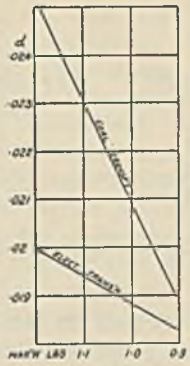

Fig. 2.

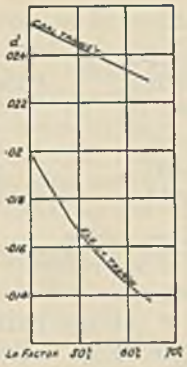

Fig. 3.

per unit will be attained for some years yet. The diagram, Fig. 2, shews these figures in the form of a graph.

Load Factor.

This is a variable that is overwhelmingly in favour of electrical transmission and is the one along which I think the greatest possibilities of development lie. The extra cost of transmitting the greater number of units of electricity is very little, as the capital losses are the same, the transformer iron losses are the same, and all that has to be increased is the copper losses. These make very little difference to the total figures, and when divided by the increased number of units, bring the cost down considerably. It is reasonable to assume that there would be some slight increase in boiler house efficiency if the load could be kept more uniform, as it would be with an improved load factor, and the figures I have set out for coal shew a reducing consumption of 1.2 lbs. per unit at 40% load factor down to 1.1 lbs. at 65% load factor.

Even after making allowance for the improved boiler house efficiency, the advantage in favour of electricity increases from 20% to 40% when the load factor is increased from 40% to 65%. Table IV. sets out these figures, with Fig. 3 shewing them in the form of a graph.

General Conclusion.

It will be seen that the line along which the greatest improvement favours electricity is in the improvement of the load factor, and this is the one that is easiest of improvement. Apart from the financial advantages which I have tried to establish, there are a number of others which will weigh the scales much more in favour of electricity, such as :—

(a) Cost of land.
(b) Local rates.
(c) Cost of labour.
(d) Ash disposal.

The one disadvantage I can foresee is political rather than economic, and deals with the greater difficulty of guarding and keeping in commission a station situated in a location more subject to unrest in times of dispute, which the coal fields undoubtedly are as compared with the towns. There is one point, however, that apparently outweighs all these, and to my mind is an overwhelming advantage in favour of electrical transmission. If the figures of progress estimated by the Electricity Commissioners are to be attained, it will be necessary for the Central Board to supply not only the consumers which the Municipalities and Power Companies have at the present time, but also the other large users who at present generate their own current. The collieries are predominant in this class of consumer in this area. When terms are offered that will appeal to these people, a line will ultimately have to be run to them from the main stations, and then the cost of this line will need to be borne as an item of distribution, whereas by adopting the plan suggested above, this cost would be saved. It surely is farcical to transport coal from Aberaman to a power station at Cardiff, and then re-transmit the energy which this colliery wants to mine this coal by means of a transmission line, following exactly the same route that the raw fuel has traversed, but in the reverse direction.

TABLE IV.—TABLE OF VARYING LOAD FACTORS.

Load Factor.	*Millions of Units transmitted.*	*Electrical Costs.*	*Coal Costs.*
40%	350	0.020d.	0.252d.
45%	390	0.182d.	0.247d.
50%	437	0.168d.	0.244d.
55%	480	0.156d.	0.24d.
60%	525	0.147d.	0.235d.
65%	568	0.138d.	0.23d.

ACKNOWLEDGMENTS.

I should like to express my indebtedness to a number of gentlemen who have made the compiling of these figures possible, among whom I would mention : Mr. J. W. Beauchamp, Central Electricity Board ; Professor E. W. Marchant, of Liverpool University ; Mr. T. E. Lewis, of Johnson & Phillips ; Mr. C. A. Smiles, of English Electric Co. ; and Mr. J. Marlow Allen, of the South Wales Coal Owners Association.

NORTH OF ENGLAND BRANCH.

Presidential Address.

SIDNEY BATES.

(*Meeting held* 17*th October*, 1931.)

Having acknowledged the honour of his election to the Presidential Chair, Mr. Bates said that though it might be thought that he had not been particularly active in the affairs of the Association, it should not be assumed that he had been out of touch with electrical engineers and their work ; a mining engineer has many anxieties in these days, particularly where the personal direction of a group of collieries is involved, but that did not detract from a full recognition of the technical ability of the electrical engineering staff upon which much of the executive work involves. Mr. Bates could speak with some authority on this matter and wished to testify to the good work the Association had done in the training of young men for mining electrical duties.

We live in an electrical environment and this has had a profound effect upon mining methods ; underground operations have been rendered safer ; working conditions have been improved and production costs have been reduced, all as a direct result of the application of electricity in and about the pits. The process may not have been rapid, but perhaps the work done has been the more thorough on that account ; for example, it is forty-three years since motor-driven ventilating fans were installed to take the place of furnace ventilation at a colliery with which at that time Mr. Bates was connected. Incidentally, the two shafts were a considerable distance apart and the ventilating costs were reduced by one-half as the result of electrification. The plant would be considered very old-fashioned in these days—it comprised continuous-current motors and

Capell fans—but this passing reference to an old electrical installation might serve as a reminder to the younger members that colliery electrification was not in itself a recent development. Later, a small generating plant of about 900 k.w. was installed and, as waste heat from coke ovens was available, the generating costs were as low as 0.08 per k.w. hour. As time went on, the main and auxiliary haulages were tackled and eventually more than three hundred ponies were brought out. So much for the results of an early colliery electrification experiment.

The modern tendency, said Mr. Bates, is to make extensive use of electricity at or near the coal face whenever that could be done with safety. It followed that there was a corresponding decline in the use of compressed air and of underground pneumatic appliances. Electricity so directly applied could not but result in lowered costs and he had noticed that even on the Continent, where the greatest care is exercised when determining air pressure when selecting compressing plant and when laying out the air-pipe system, the resultant working costs were not all that could be desired. He trusted that designers and others would continue to exercise their skill in the development of electrical appliances of all kinds which could be used at the coal face with safety, and that they would continue to take full advantage of the sound advice which H.M. Electrical Inspector of Mines was always willing to afford.

The electrification of haulage systems in the pit perhaps presented less difficulty from the safety point of view, but he would suggest that it offered a problem to which modern ideas should be directed, for haulage costs could be a serious source of worry in these days.

Having spent three months in America, Mr. Bates had the privilege of inspecting the underground workings of several mines where heavy electric locomotives were employed with surprisingly good results. He realised, of course, that the Mine Regulations in this country are more stringent but, what was brought to his notice during the course of the tests undertaken some years ago at the suggestion of the late Mr. C. P. Markham, led him to believe that where the haulage roads were suitable there was a good deal to be said in favour of the use of properly constructed and comparatively heavy battery locomotives on the main haulage roads, with lighter locomotives for inbye service. The cars commonly used in the States had a capacity varying from three to five tons ; the smaller locos. were a combination of battery and trolley system and in face work that system did remarkably well.

Mr. Bates had noticed that later in the Session a Paper was to be presented dealing with centrifugal pumps for collieries and he was pleased that this Branch of the Association had not neglected to consider that matter at a time when extensive plant replacement was being undertaken as a result of the Frequency Standardisation Scheme ; centrifugal pumps were of major importance where colliery working was concerned and the application of electricity to this service had revolutionised pumping plant designs. Large quantities and high heads could be dealt with at a moderate cost and he had in mind a 4000 gallons per minute 380 ft. head motor-driven single-stage centrifugal pump, the capital cost of which corresponded to no more than half the cost that was involved in building an underground pump-house to accommodate a compound double acting ram pump of equal capacity.

He had also noticed that a Paper was to be read by one of the Cumberland Sub-Branch Members dealing with recent improvements in underground illumination. He would suggest that was a subject about which exhaustive investigation was very desirable with a view to the reduction in accidents and working costs which would result inevitably from more adequate lighting of the working places in the pit. The changeover operations which were being undertaken in the local coalfield by the Newcastle-upon-Tyne Electric Supply Co., Ltd., and other Authorised Undertakings afforded an excellent opportunity for the re-arrangement of the colliery electrical plants to the best advantage. He would say those operations could hardly help but lead to a more extensive use of electricity for mining purposes. He had visited French and German mining localities on more than one occasion and the extended use of electrical apparatus was more perceptible at each visit. Large generating units were being installed and high efficiency working was the rule, particularly with the advent of pulverised fuel burning. Boilers capable of producing 200,000 lbs. of steam were very useful. The citation of these foreign examples was not to say that there were no highly efficient self-contained generating plants in the North-East Coalfield, and he had in mind an installation where the generating cost works out at 0.36 of a penny per k.w. hour. In that connection, however, he should explain that heavy pumping services were provided and the generating plant was, as a result, operating at very nearly a 100% load factor.

In a letter which the Honorary Secretary of the Branch had circulated to the members there was an intimation as to the possibility of the status of mining electrical engineers being certified by compulsory examination. Mr. Bates said he believed certification was coming because the electrification of our collieries was proceeding apace and because the proper maintenance and operation of electrical plant called for particular electrical training and experience, but he trusted they would all agree that though a change might be desirable in course of time the engineers of our collieries must be engineers.

Mr. S. BURNS proposed that the meeting accord its best thanks to Mr. Bates for his Address. He did so with real pleasure because he could claim to be in some measure responsible for Mr. Bates having been invited to occupy the Presidential Chair of this Branch of the Association. Mr. Burns said he had always urged that a mining engineer of recognised standing in the Northumberland or Durham Coal Trade, was the desirable Chairman, and they looked with confidence to Mr. Bates to serve the Branch as faithfully as a long series of Colliery Agents and others had served it in the past. Mr. Bates had little leisure time and the responsibility of direction of three groups of Collieries must involve him in many cares in these days ; Mr. Burns would assure him they were not unaware of the circumstances and loyal support during his term of office could be relied upon.

Mr. Burns said he was heartily in sympathy with Mr. Bates' concluding paragraph. We heard a great deal about compulsory certification nowadays and though the extended application of electricty to main colliery services undoubtedly called for greater electrical knowledge than formerly upon the part of those who must operate and maintain these plants, Mr. Burns would suggest that unless they were careful they might mistakenly give less credit than was fairly due to the engineer of mechanical training. A mining electrical engineer must be an engineer first, last, and all the time.

Mr. S. A. SIMON expressed his pleasure in seconding the vote of thanks. He did not seek to enter into

anything in the nature of a discussion, but when Mr. Bates mentioned the earlier attempts at electrification he could not help thinking what remarkable strides had been made in the application of electricity to mining, as was forcibly evidenced at the recent Coal Face Machinery Exhibition in Sheffield. Those of the members who, like the speaker, were there would agree with him that the machinery exhibited was of very highly developed type for specific purposes, and that it mainly embodied electrical principles as the basis of design. There was no doubt that that sort of machinery would be used more and more extensively in collieries in the future and it would require a very high degree of both mechanical and electrical skill and intelligence for its proper maintenance in good working order. More electrically trained men would be required with such machines, which would displace unskilled workers, ponies, etc. That was one of the most important spheres in which the Association could be of advantage to many of its members.

Another point which Mr. Simon would like to mention, one constantly reiterated by H.M. Electrical Inspectors of Mines, namely that apparatus was most beautifully designed to promote safety, but a little personal carelessness might entirely nullify the safety precautions on which so much thought and trouble had been expended. The safety and efficiency of apparatus, in the last issue, depended upon the skill the intelligence and the conscientiousness with which the electrician did his duty, and that again emphasised the opinion of Mr. Bates, that the electrical engineer and electrician must be an engineer first, foremost and last.

KENT SUB-BRANCH.

Modern Methods of Cable Fault Location: The Murray Loop Test.

J. URMSTON.

In the absence of the Author the paper was read by Mr. F. S. Smith.

(*Paper read 14th March,* 1931.)

The modern tendency in the art of fault location is to use the Wheatstone Bridge principle, either as a d.c. or an a.c. Bridge. The d.c. Bridge in the form of a Murray Loop is used for locating faults to earth, and faults between cores, such as normally develop in modern types of cable with efficient systems of protection. The a.c. Bridge is employed for locating broken conductors and severe short circuits involving all the cores of a cable.

The older, and perhaps better known methods of location, such as the Fall of Potential Test, the Ballistic Capacity Test, and the Induction Test, may still be usefully employed under certain circumstances, but modern conditions lead to the Murray Loop Test as the primary method of location and it is with this in its various forms that this paper deals.

TABLE I.

LOCATION OF CABLE FAULTS.

Type of Fault.	*Type of Bridge.*
1. Conductor to Earth	D.C. (Murray Loop)
2. Short between Conductors	D.C. (Murray Loop)
3. Short between all Conductors	D.C. or A.C.
4. Short between all Conductors and to Earth	D.C. or A.C.
5. Severed Conductors	A.C.
6. Severed Conductors and to Earth	A.C.

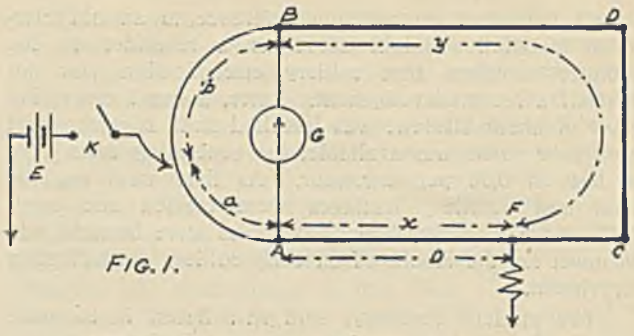

FIG. 1.

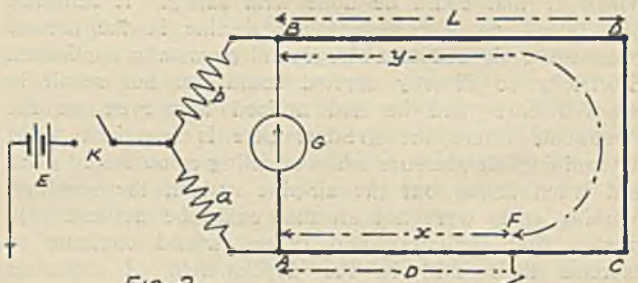

FIG. 2.

$$D = \frac{a}{a+b} \cdot 2L$$

Preliminary Tests.

The actual form of Murray Loop Test to use with a particular fault will depend on the type of fault, and the first essential is therefore to be able rapidly to classify the failure. A Megger provided with shunts should always be available as this is the best type of instrument with which to make the preliminary tests. Insulation tests are carefully noted from one end of the faulty section and then the far end conductors are shorted and earthed, and a further insulation test taken to prove whether any of the conductors are severed. A copper resistance test is advisable, in case the cores are severed and yet the resistance at the break is too low to indicate on the Megger, but this is not usually done unless the system is known to be liable to such a type of fault.

The Megger Test will indicate one of the following failures (see Table I.) :

1. Conductor to earth.
2. Short between conductors.
3. Short between all conductors.
4. Short between all conductors and to earth.
5. Severed conductor.
6. Severed conductor and to earth.

Faults 1, 2, 3 and 4 can generally be located by the Murray Loop Test, but faults 5 and 6 cannot be located by this means unless they also involve faults of the type 1, 2, 3 or 4, as is commonly the case.

Simple Loop Test.

This test is used for locating faults of the types 1 and 2, when there is a sound conductor available for looping to the faulty conductor.

Fig. 1 shews the arrangement when a Slide Wire or Low Resistance Bridge is connected directly to the ends of the cable.

Fig. 2 shews a similar arrangement using a Bridge having high resistance arms, such as a P.O. Box.

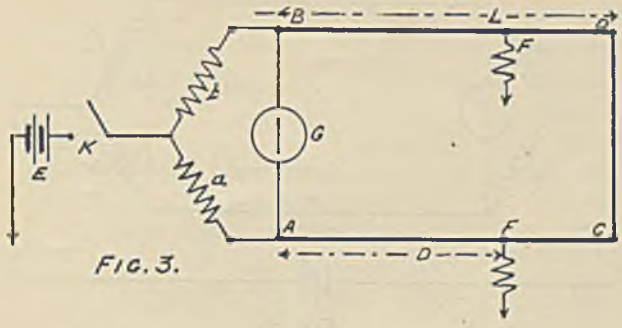

FIG. 3.

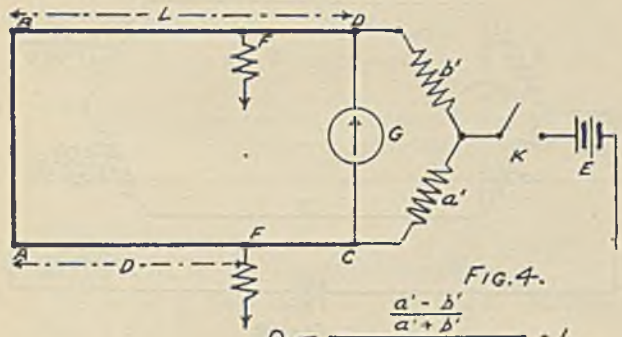

FIG. 4.

$$D = \frac{\frac{a' - b'}{a' + b'}}{\frac{a' - b'}{a' + b'} + \frac{a - b}{a + b}} \cdot L$$

In the latter case it will be noticed that the galvanometer is connected to the ends of the cable cores so that the leads from the bridge to the cable become part of the resistance arms. Even if these leads are of considerable length they may be neglected in comparison with the resistance of the bridge arms.

Referring to Figures 1 and 2:

AC is the faulty conductor with the fault at F.
BD is the sound conductor looped to AC at D.
E is the battery.
G is the galvanometer.
K is the battery switch.
x is the conductor resistance from A to the fault F.
y is the conductor resistance from B to the fault F.
a is the resistance of the bridge arm adjacent to the faulty conductor.
b is the resistance of the bridge arm adjacent to the sound conductor.

To make the test, the resistance, a, is varied until there is no deflection of the galvanometer needle, when the battery switch is closed. A small battery voltage is first used, which is then increased until a sufficiently sharp balance point is obtained.

For the balance condition we have:

$$\frac{a}{b} = \frac{x}{y}$$

$$\text{or } \frac{a}{a + b} = \frac{x}{x + y}$$

$$\text{or } x = \frac{a}{a + b}(x + y)$$

If the loop is of uniform resistance throughout, and if the resistance of the loop connection can be neglected, we may say:

$$D = \frac{a}{a + b} 2L$$

Where D is the distance of the fault from end A, and L is the length of the cable route.

It will be seen that this result is very simple; especially in the case of the Slide Wire Bridge, where a will be the number of slide wire divisions recorded and a + b will be the total divisions on the whole slide wire.

In order to check the location, it is advisable to make a second test from the opposite end of the cable.

This further test is carried out in precisely the same way, and the sum of the distances to the fault should equal the length of the cable route.

Overlap Loop Test.

This test may be used for locating faults of the types 3 and 4, provided there are two cores with different fault resistances to earth or to a third core.

If the fault resistances are equal, they must be made unequal by further breaking down one core to earth.

The test really consists of a combination of two simple loop tests. One test is made from one end of the cable and then another test is made from the opposite end of the cable, at as nearly as possible, the same time. If there is only one operator and one bridge, the change from one end of the cable to the other must be made quickly; it is, in fact, best to make two or three changes from end to end to ensure that the fault resistances have not materially altered during any two consecutive tests.

Figs. 3 and 4 shew the connections for making the tests when using a high resistance bridge.

AC is one faulty conductor with the fault at F.
BD is another faulty conductor with the fault also at F.

When a balance is made from one end of the cable, let the resistances of the bridge arms be a and b; and when the test is made from the opposite end of the cable, let the resistances be a′ and b′ respectively.

The distance of the fault from the end where the first test is made will then be given by

$$D = \frac{\frac{a' - b'}{a' + b'}}{\frac{a' - b'}{a' + b'} + \frac{a - b}{a + b}} L$$

If a slide wire bridge is used in place of the high resistance bridge, the formula can be simplified, since $a + b = a' + b'$ making

$$D = \frac{(a' - b')}{(a' - b') + (a - b)} L$$

This test appears to be little known as many engineers consider it impossible to do a loop test with two faulty cores. The method, as a matter of fact, is quite accurate, and the formula should always be applied in cases where an overlap is obtained when making loop tests from both ends of a cable.

The following is the proof of the formula: Fig. 3 may be redrawn as in Fig. 5.

The delta resistances 2y, f_1 and f_2 may be converted to an equivalent star arrangement as in Fig. 6.

Resistance $\frac{f_1 f_2}{2y + f_1 + f_2}$ is the battery circuit and so does not alter the bridge conditions.

For balance we have :

$$\frac{a}{b} = \frac{x + \dfrac{2y\ f_1}{2y + f_1 + f_2}}{x + \dfrac{2y\ f_2}{2y + f_1 + f_2}} = \frac{2xy + xf_1 + xf_2 + 2yf_1}{2xy + xf_1 + xf_2 + 2yf_2}$$

2xy is of the second order of smallness and may be neglected.

$$\therefore \frac{a}{b} = \frac{xf_1 + xf_2 + 2y\ f_1}{xf_1 + xf_2 + 2y\ f_2}$$

$$\text{also } \frac{a - b}{a + b} = \frac{2y\ (f_1 + f_2)}{2\ (x + y)\ (f_1 + f_2)}$$

Similarly for the test from the opposite end of the cable.

$$\frac{a' - b'}{a' + b'} = \frac{2x\ (f_1 + f_2)}{2\ (x + y)\ (f_1 + f_2)}$$

$$\frac{\dfrac{a' - b'}{a' + b'}}{\dfrac{a - b}{a + b}} = \frac{x}{y}$$

$$\text{or } \frac{\dfrac{a' - b'}{a' + b'}}{\dfrac{a' - b'}{a' + b'} + \dfrac{a - b}{a + b}} = \frac{x}{x + y}$$

$$\text{or } D \frac{\dfrac{a' - b'}{a' + b'}}{\dfrac{a' - b'}{a' + b'} + \dfrac{a - b}{a + b}} L$$

Fisher Loop Test.

This test is used for locating faults of the types 1 and 2 when there is no sound core for looping, and also for faults of the types 3 and 4 when the overlap method fails.

Two auxiliary leads are required for making a loop, but these may be of any length or cross section. On short runs of cable, temporary leads may be run, whilst for long lengths, a pilot or telephone cable may be utilised successfully.

The test again consists of a combination of two simple loop tests, but this time both are made from the same end of the cable. The first test is shewn in Fig. 7 and is an ordinary loop test, utilising one of the auxiliary wires as the sound conductor.

In the second test (Fig. 8) the second auxiliary lead is used as a battery lead instead of putting the battery to earth.

AC is the faulty conductor with the fault at F.

MC is an auxiliary sound conductor connected to AC at C.

NC is another auxiliary sound conductor also connected to AC at C.

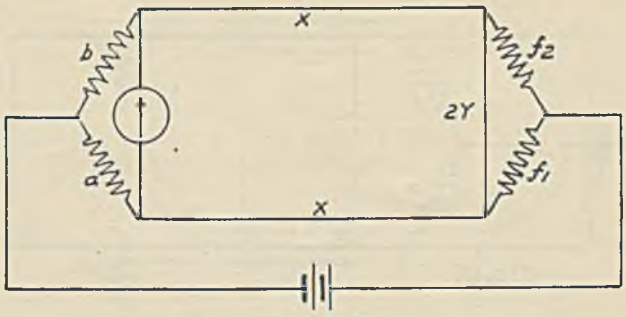

FIG. 5.

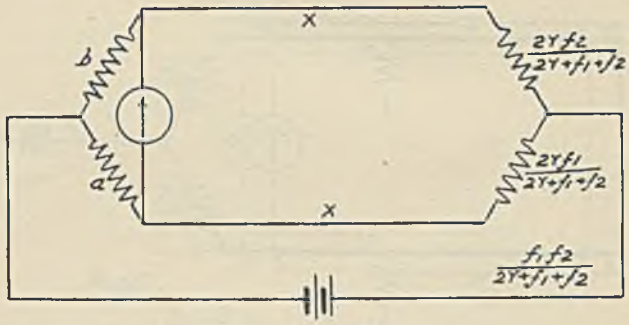

FIG. 6.

If a and b are the readings obtained for balance with the battery connected to earth and a', b', are the readings with the battery connected to the auxiliary wire, then the distance to the fault will be

$$D = \frac{a\ (a' + b')}{a'\ (a + b)} L$$

If a slide wire bridge is used, this is simplified to

$$D = \frac{a'}{a'} L$$

It will be noticed that this result is independent of the resistances of the auxiliary leads, and these may therefore be of any size or length.

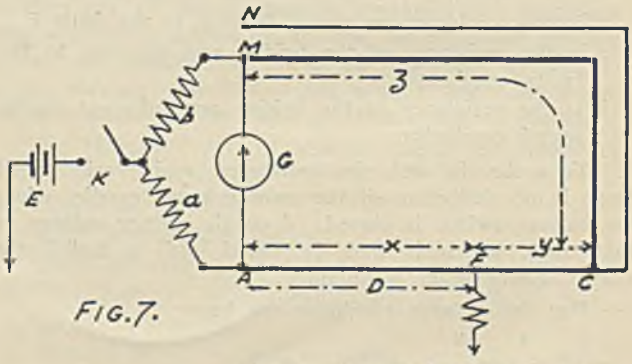

FIG. 7.

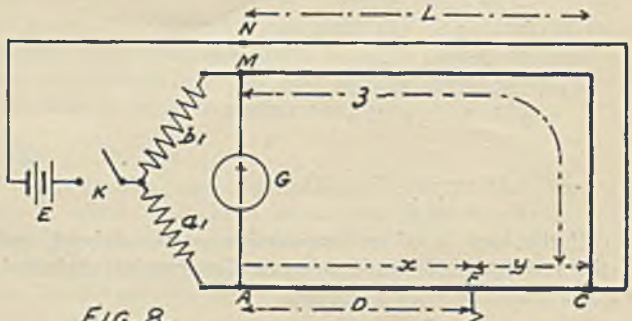

FIG. 8.

$$D = \frac{a(a' + b')}{a'(a + b)} \cdot L$$

TABLE II.

NEWTOWN COLLIERY CO.

11 k.v. Feeder. Power House—Newtown Village Kiosk. Laid 1925.

Section No.	Locality.	Size Sq. Inch.	Section Length yds.	Actual Length from Power House.	Equiv. .10 sq.in. Length from Power House.	Remarks.
1	P.H. Switchgear to 9′ 0″ E. of Main Entrance Gate	.15	110	110	75	—
2	9′ 0″ E. of Main Entrance Gate to outside No. 4 Rose Villas	.10	202	312	277	20yds. laid thro pipes on bridge
3	Outside No. 4 Rose Villas to 'T' Box at London Road Corner	.10	201	513	478	—
4	'T' Box at London Road Corner to Newtown Village Kiosk	.06	68	581	592	Includes 3′ 0″ rubber tails

NOTE :—To convert equivalent .10 sq. in. cable to actual .15 sq. in. cable multiply by 1.46
To convert equivalent .10 sq. in. cable to actual .06 sq. in. cable multiply by 0.595

A check location may be made from the opposite end of the cable if this is considered necessary.

The proof of the formula is quite simple. Referring to Figs. 5 and 6.

$$\frac{a}{b} = \frac{x}{y+z} \text{ or } \frac{a}{a+b} = \frac{x}{x+y+z}$$

$$\text{also } \frac{a'}{b'} = \frac{x+y}{z} \text{ or } \frac{a'}{a'+b'} = \frac{x+y}{x+y+z}$$

$$\text{therefore } \frac{x}{x+y} = \frac{\dfrac{a}{a+b}}{\dfrac{a'}{a'+b'}} = \frac{a\,(a'+b')}{a'\,(a+b)}$$

or if the faulty conductor is of uniform cross section throughout,

$$D = \frac{a'\,(a+b)}{a\,(a'+b')}\,L$$

High Tension Loop Test.

This test is identical with the simple loop test, with the exception that a high tension source of supply is used in place of a battery. The test is used for the location of high resistance faults of the types 1 and 2, such as usually occur in E.H.T. and supertension cables.

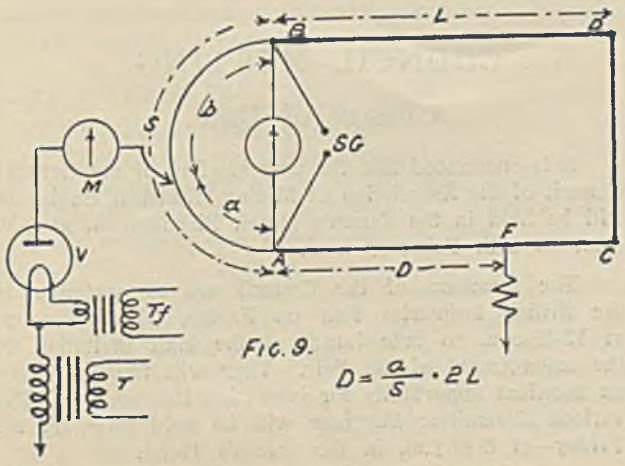

FIG. 9.

$D = \frac{a}{s} \cdot 2L$

Fig. 9 shews the connections. A slide wire bridge is used, this being specially insulated to withstand a high pressure to earth. The spark gap, SG, is provided for protecting the galvanometer from sudden current surges.

The high tension d.c. is derived from a high tension transformer, T, connected to a rectifying valve, V. The filament of the valve is heated by means of a step-down transformer, Tf, insulated between windings, and the rectified current is measured by means of the milliammeter, M.

High tension faults seal up rapidly and the Megger test may shew two or more megohms soon after the fault. The high tension bridge is set up and an increasing voltage applied by regulating the primary supply to the step-up transformer, until a current of 5 milliamps. is passing through the fault. A rough balance is made and then the current is increased to 25, or even 50, milliamps. and an accurate balance obtained.

In making this test great care must be taken to avoid getting in contact with the bridge or galvanometer, as these may be at a potential of several thousand volts above earth.

The high tension test, as it is called, has become firmly established and has abolished the practice of breaking down high resistance faults by repeated switching in of the faulty cable.

This latter method is never advisable, as apart from possible damage to transformers and other parts of the system, it sometimes leads to the fault becoming an open circuit, making a more difficult location.

It is found that the H.T. loop test may often be employed to locate faults where all cores are faulty, and also in cases where one core is faulty in more than one place.

This becomes possible due to the fact that although two cores may both have a resistance of say half a megohm to earth, one core will suddenly break down to a resistance of a few thousand ohms when d.c. pressure is applied, thus relieving the pressure on the other core, which will remain steady at half a megohm. The high tension loop test, undoubtedly, will be further developed for making tests on cables of all voltages.

Interpretation of Test Figures.

After one or other of the foregoing tests has been made, it becomes necessary to determine the actual geographical position of the fault. For this purpose, it is essential to have an accurate schedule (see Table II.) and plan, shewing the route and the position of the joints. If there is any change of cross section in the cable, such change must be allowed for, by converting the actual length to an equivalent length of normal cross section.

The conversion is simply made so long as it is remembered that to convert a length of cable of small cross section to an equivalent length of larger cross section, the length must be increased in proportion to the section, and to convert to a smaller cross section, the length must be diminished.

The nominal cable cross sections are only approximate and the actual area or resistance must therefore be used. For example :

0.1 sq. in. cable has an actual area of 0.1009 sq. in.
0.15 sq. in. cable has an actual area of 0.1478 sq. in.

Therefore, to convert 0.1 to 0.15 sq. in., we multiply by $\frac{0.1478}{0.1009}$ i.e. by 1.46.

The route schedule should give at a glance the equivalent length to each joint position, and such a schedule may include sections of overhead line as well as cable.

When using the slide wire bridge it is sometimes necessary to employ long leads, and these must be considered as part of the cable route and must be expressed as so many yards of equivalent cable. The route length of the cable will be increased by this amount as also will the equivalent length of each joint position.

If the fault is not in normal section cable, it will be necessary to reconvert from equivalent to actual length to find the exact location of the fault in relation to the nearest joint position on the Schedule. The position of the fault may finally be marked on the plan and the necessary ground excavated.

Conclusion.

The four variations of the Murray Loop Test described, will cover a very large percentage of cable and box failures. At the same time, the tests are very simple and require little apparatus excepting when it is necessary to use the high tension set. Suitable instruments are manufactured by several English firms as also are H.T. Valve equipments. The first cost of such apparatus is often recovered in a single test by the time saved in making an accurate location.

The accuracy with which a location can be made with the Murray Loop Test under good conditions is surprising, and inaccurate interpretations of the test readings or inaccurate records of lengths are more often than not, the sole cause of a poor location.

After reading the paper, Mr. Smith gave a demonstration with a High Tension Testing Set.

A length of 600 volt lead covered cable was subjected to a d.c. pressure of 30,000 volts between cores and sheath but shewed no signs of failure. An a.c. pressure was then applied and the cable under test broke down at a pressure of 15,000 volts. A Murray Loop Test was then made, a pressure of nearly 2000 volts having to be applied before sufficient fault current flowed to produce a reading.

After the location was made, a three inch piece of cable was cut out, the lead sheath was removed, and the fault was found, exactly as calculated, in the middle of this length.

FIFE BRANCH.

Mining Type Induction Motors.

GEORGE HENDERSON.

The 1931-32 Session was opened on the Friday, 29th October, in the Mining School, Cowdenbeath, when Mr. George Henderson of Messrs. Bruce Peebles, Edinburgh, gave a lecture on "Induction Motors". Apologies were intimated from Mr. Charles C. Reid, President, and Mr. R. W. Peters, Vice-President.

Mr. James Dawkins, Vice-President, occupied the Chair and there was an excellent and representative attendance.

Mr. Henderson's opening remarks dealt with the factors affecting the standardisation of motors from the aspects of manufacture and sales. Later he developed the construction and design of motors, emphasising the points which required to be kept in mind—particularly in dealing with the application of motors to mining work. Mr. Henderson demonstrated very clearly the advantages and disadvantages of the various types of motor windings and concluded his remarks in an excellent resumé on the latest practice in motor design.

At the close of the lecture, which was illustrated by lantern slides, a most interesting discussion took place, among the contributors being Messrs. Neillands, Rutherford, Dawkins, Roberts and Dr. Parker.

Mr. Henderson was accorded a very hearty vote of thanks, and it was agreed to print the paper privately among members of the Fife Branch. The Chairman intimated that a full programme for the new Session had been completed. One meeting has been reserved for a paper from a working colliery electrician and Mr. Dawkins expressed the hope that there might be several of these papers forthcoming, so that the Prizes Committee might decide which paper should be recommended for presentation at the branch meeting.

COUNCIL MEETING.

Change of Date.

It is announced that the next meeting of the General Council of the Association of Mining Electrical Engineers will be held in the Queen's Hotel, Birmingham, at 9-30 a.m., on 27th February next.

The members of the Council are to assemble at the British Industries Fair on Friday, 26th February, at 12-45 a.m. to take Lunch at the kind invitation of the management of the Fair. They will thus be given an excellent opportunity for inspecting the exhibits. The various Committee Meetings will be held later on the Friday—at 8-30 p.m. in the Queen's Hotel.

Manufacturers' Specialities.

Cardiff Engineering Exhibition.

The Cardiff Engineering Exhibition promoted by the South Wales Institute of Engineers, has become definitely established as an important annual event in the business world of South Wales. The success and popularity of the exhibition, which this year occupies the Greyfriars Hall in Cardiff from November 18th to 28th, are as pronounced as ever. It is a noteworthy feature that year after year the names of certain keenly progressive and important engineering firms recur in the list of exhibitors. The following brief notes of some of the more prominent exhibits, being written prior to the opening date, are mainly based upon advance information provided by Mr. Martin Price, Secretary of the South Wales Institute of Engineers, who is responsible for the organisation and management of the show. They will, however, serve to indicate the particular class of goods calculated to meet the modern requirements of the coal and iron industries of the district.

THE A.M.E.E.

Before dealing with the purely trading elements it is well to mention that the South Wales Branch of the Association of Mining Electrical Engineers have planned to take advantage of the fine opportunity offered for wide-spread propaganda work. An attractively arranged information bureau is to be the centre for impressing upon visitors the valuable position which the A.M.E.E. occupies in the development of the technical side of mining.

THE ELECTRIC CONSTRUCTION Co., Ltd.

Principal items in the E.C.C. range of exhibits include: a 100 B.H.P. "Lokaveay" totally enclosed air-blast, self-cooled, squirrel-cage motor, 400 volts, 50 cycles, three-phase, 750 r.p.m., arranged with stator windings to give—with the use of a condenser—a high power factor. An oil-immersed throw-over switch for the "Lokaveay" motor. A 6600 volt, sheet-steel cubicle, with oil-immersed circuit breaker, 250,000 k.v.a. breaking capacity. A 20 B.H.P. "Human" starter, for use with a squirrel-cage motor, and to improve the power factor. A ringing motor-alternator set, consisting of a three-phase motor-alternator and interrupter gear, and an industrial type starter for the motor-alternator set. Samples of collectors and brushgear for three-phase motors, and plugs and brushgear for rotary converters. An E.C.C. direct current generator is also to be exhibited.

THE ENGLISH ELECTRIC Co., Ltd.

Interesting exhibits to be seen on the English Electric Company's stand comprise the following: a flame-proof mining switch of the self-isolating draw-out type, suitable for pressures up to 3300 volts. A special feature of this switch is that the meters are of the "plug in" type.

A truck type switch pillar, suitable for use on systems up to 6600 volts. The truck comprises a fixed sheet steel housing and a moving truck portion. When in operation the whole of the apparatus is enclosed and completely vermin-proof. An S.S. oil circuit breaker for induction motor control. This switch is ironclad and fitted with full automatic protection.

A mining type liquid controller which embodies an oil-immersed reversing contactor, a liquid regulator and a combined lever, frame and master switch.

English Electric machines to be shewn include a "Closvent" motor which is suitable for dusty or corrosive atmosphere condition. Other motors exhibited will include slipring and squirrel-cage explosion-proof motors and several of the industrial type.

A 25 k.v.a. single-phase transformer with a ratio of 10,500/237 volts and a 25 k.v.a. three-phase transformer with a voltage ratio of 10,500/410. These are included as being typical of the latest requirements for rural electrification.

An automatic control equipment for induction regulators and an automatic induction regulator for small low voltage distributors: this regulator has a big field of application for voltage regulation on low voltage distribution networks. Another interesting English Electric exhibit is an electric induction type roll heater which ensures uniform heating and less scrap material.

EVERSHED & VIGNOLES Ltd.

On this stand is to be exhibited the Evershed-Midworth system of repetition, summation, and distant control. By this system the indications of any electrical or mechanical instrument, or originating movement, can be repeated to one or more desired positions. Electrical or other quantities of a different character can be summated at a distance and any kind of machinery can be distantly controlled. The system is fully automatic, flexible and economical, and has been applied to electric power stations, railways and waterworks, etc.

A full range of the "Megger" and "Meg" group of insulation and resistance testing sets will be on view and amongst these will be shewn the "Meg" earth tester, a cheap and light-weight instrument by which systematic routine tests of the "Earthing" of electrical systems can be carried out. This instrument gives a direct reading in ohms of the resistance to earth, without calculation or adjustment, and the reading is unaffected by soil electrolysis or vagabond currents.

Single, duplex and multiple recorders of the well-known Evershed type will be shewn: these are available in three distinct designs to meet the demands of every purpose in all industries.

GENT & Co., Ltd.

An attractive display will include "Tangent" electro-motor syrens for fire-alarms and for far-reaching sound signals in collieries and large works: "Tangent" staff locators, for locating immediately the principal or his colleagues in business works, etc., for urgent business calls: "Pul-Syn-Etic" electric clocks and time discipline apparatus, drum clocks, turret clocks, automatic start and cease work signals for all purposes. "Tangent" water and liquid level apparatus for indications and sound signals.

HASLAM & STRETTON Ltd.

The exhibits on this stand will be of particular interest to mining electrical men. These include a novel form of electric vulcaniser, specially adapted to deal

with trailing cable, but also eminently suitable for vulcanising conveyor belts, fire hose, and many other articles for colliery and works' use. Actual demonstrations of this machine repairing trailing cables will be carried out daily and the firm will be glad to effect repairs of trailing cables for any customer.

Special attention should be called to the "Allgrip" clips for use with steel arches. An illustrated description of these valuable accessories to modern mining methods was published in our last issue.

CROMPTON PARKINSON Ltd.

A special display of lamps manufactured by Crompton Parkinson, Ltd., will also be shewn by Haslam & Stretton Ltd., who are the official distributors of these lamps in South Wales.

A. REYROLLE & Co., Ltd.

This year A. Reyrolle & Co., Ltd. are to shew examples of their flame-proof plugs and sockets on the stand of their agents Haslam & Stretton, Ltd. The plugs are rated at 5 amperes, 15 amperes, 60 amperes and 100 amperes, and are specially designed for use in mines or other places where flame-proof enclosure is essential.

J. H. HOLMES & Co., Ltd.

On the same stand this firm, which is associated with Messrs. Reyrolle, will shew a flame-proof motor. These machines are of particularly robust construction, have strongly-ribbed frames and wide metal-to-metal flanges to secure flame-proofness; in addition, cup washers on each bolt ensure that no unauthorised person can tamper with them. The particular motor to be shewn is 6 B.H.P. at 710 r.p.m. on a 400 volt, 50 cycle, three-phase supply.

Overhead Line Pole-mounting Switch-fuses.

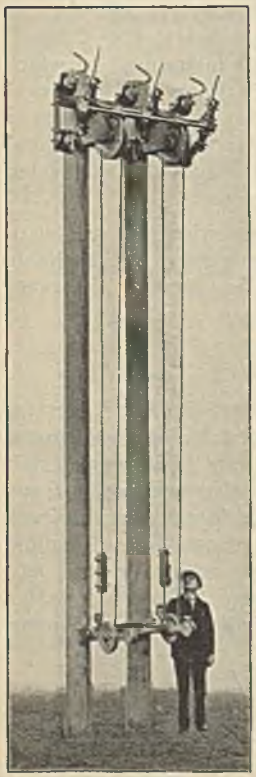

Fig. 1.

The illustrations herewith shew the general details of a new pole line switch-fuse recently introduced by George Ellison Ltd. These switch-fuses are for use on overhead power lines where a connection is made for a branch circuit or for a transformer, to serve as disconnectors and to give automatic protection against overloads and faults. As will be seen the particular feature of the design is that the switch can be opened or closed from the ground level without the use of any other appliance or tool and the fuses can be lowered by turning a handle to bring them to a convenient position for renewal by a man standing on the ground.

A novel arrangement of steel rope and pulley mechanism, which is patented, winds the set of fuses up or down. The fuse carrying structure, being counter-balanced, is raised with little effort and rides easily

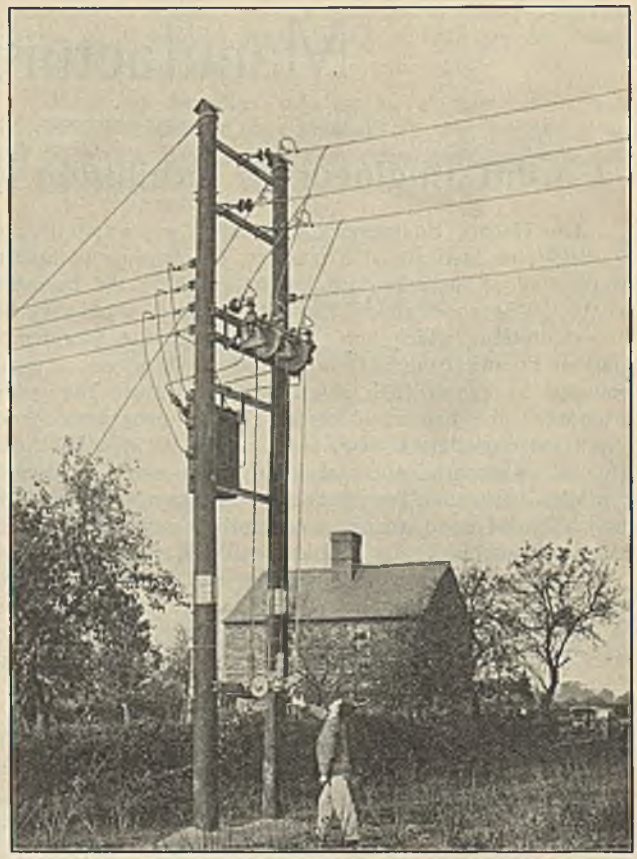

Fig. 2.—A Switch-Fuse at a Power Line Tapping.

over the top of the pulleys at the pole top to engage with the fixed contacts in perfect alignment. The fixed insulators are so disposed in relation to the upper pulley centres that, by turning the handle the fuse holders are withdrawn to a more or less horizontal position exactly as a switch.

The fuse holders may be padlocked withdrawn as a switch in its "off" position, or in the "on" position, or at any point of their travel from the contacts to the completely lowered position. The circuit is broken at the higher contact jaws first, just as a knife switch opens, so that any magnetising current which may be flowing would be broken on the contacts fitted with the horn breaks. The switch-fuses are designed for pressures up to 11,000 volts and currents up to 100 amperes.

A strong steel framework for fixing to the pole top carries a set of switch contacts mounted on pin-type metal-capped porcelain insulators with terminals for connecting the overhead wires.

Two endless steel wire ropes working in parallel are carried round a pair of metal pulleys fixed to the switch framework and another pair fixed at the operating position lower down the pole. These ropes are maintained at correct tension by jockey pulleys which take up any variation in the length due to changes of temperature.

The lower pair of pulleys are fitted to a shaft which can be turned by hand by the crank handle and which is supported on the pole by a simple frame which also carries the jockey pulleys.

Attached to the steel ropes horizontally, in a manner enabling them to ride on the upper pair of pulleys, are two tubular members to which the fuse holders are fixed. The fuse holders are well proportioned hollow ribbed porcelain cylinders with switch blade contacts

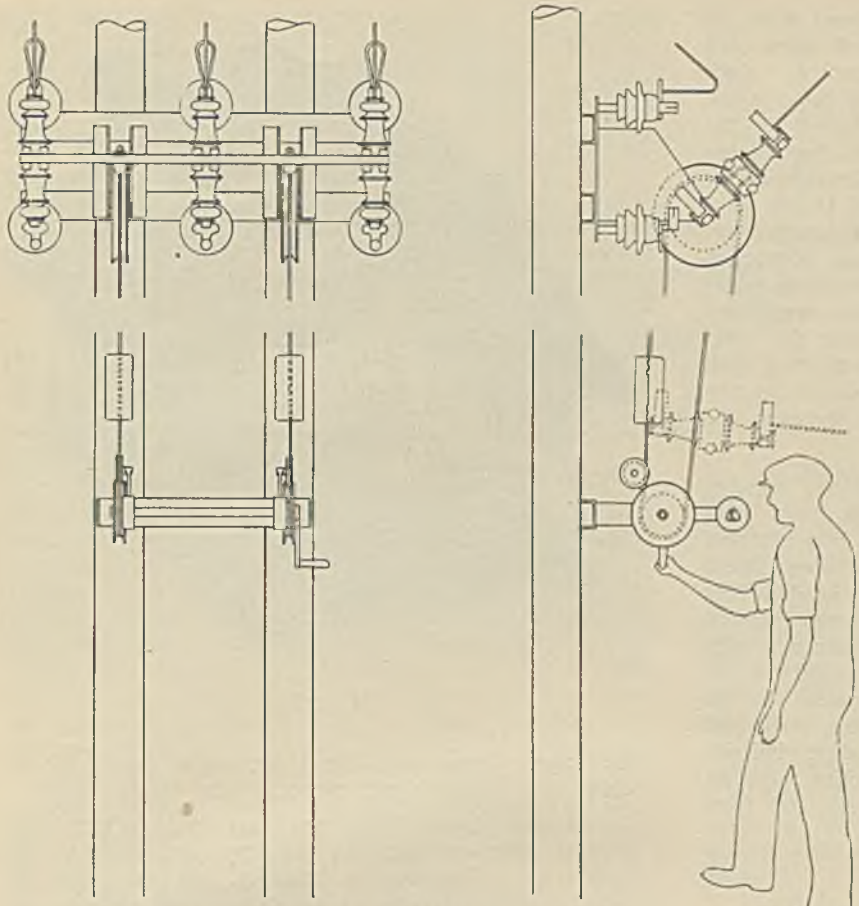

Fig. 3.—Shewing Details of the Switch-Fuse.

fitted at each end with brass clamps. A silver fuse wire is passed through the cylinder and connected to the contacts.

The turning of the handle of the lower pair of pulleys winds the steel ropes, causing the fuse carrying members to travel from the "on" position first in a circular movement, withdrawing the fuse holders from the fixed contacts and then vertically downward until arrested by the counterweights checking at the upper frame.

The "Chalk" Water Tube Boiler.

The design of steam power plants has undergone many developments during recent years in order to meet the growing demand for steam power. Many improvements and innovations have been introduced to improve both the performance and the output of the plant. On the one hand is seen the trend towards higher steam pressures and, to a lesser degree, towards higher steam temperatures ; and on the other hand, attention is turned to recovering a proportion of the heat normally lost at the exits of the plants. The air heater, a modern adaptation of the steam plant, in addition to recovering heat from the exhaust gases, provides for an accelerated and more perfect combustion by supplying combustion air at high temperature.

In the turbine, apart from the desire to utilise steam at high pressure and temperature, there is an increasing tendency to take steam from certain stages, either to use the heat in such steam for the purpose of heating the feed water, or to re-heat such steam prior to its return to the turbine for the completion of the expansion. This departure, which is sound, is subject to many restraining influences ; for instance, in the case of steam re-heated by means of a re-heater installed in the boiler considerable advantage may be lost if the boiler is set at some distance from the turbine, thus involving heat losses in the long pipe lines and the requisite pressure drop. Alternatively, if the steam is re-heated by means of high pressure steam the resulting temperature of the steam does not appear to be high.

The tendency today is to allocate one boiler to supply the steam for one turbine, and this coupled with the increasing dimensions of the turbine has necessitated boilers of considerably greater capacity, as seen by the existence at the present time of one boiler to supply the steam for an 80,000 k.w. turbine. It became clear that to give accommodation in this respect a review of boiler design was necessary. The desirability for subjecting maximum possible heating surface to the radiant heat from the furnace became evident, and in addition to improved arrangement of the tubular heating surface to achieve this aim, water cooled walls became an integral part of the boiler proper.

Water cooled walls have for years been used in conjunction with pulverised coal firing of boilers, and during this time has amply justified its existence. The capacity of the boiler is increased, the "outage" hours reduced. The maintenance costs of the furnace walls are reduced and, further, repairs are more quickly carried out in view of the smaller heat content of the walls. It is now becoming common practice to install water cooled walls in boilers fired by stokers.

Thus, with the plant comprising air-heater, economiser, re-heater, feedheaters, it is not surprising to find that the boiler heating surface constitutes only a small percentage of the total heating surface of the plant : in certain cases it amounts to only 12.5 per cent. It becomes interesting therefore, to study the trend of boiler design to meet these developments of the plant, and the Chalk Boiler here described is worthy of close attention. The illustration, Fig. 1, shews the latest development of this boiler arranged for pulverised coal firing. It will be seen that a very large tube area is presented to the radiant heat from the furnace, while, at the same time, ample provision is made for efficient heat absorption by convection currents to the rear of the boiler. The boiler consists essentially of two main banks of tubes on either side, one, the primary bank, being being built up of tubes communicating with headers forming sectional units disposed over a combustion chamber substantially triangular in shape, and the other, or secondary bank, being closely spaced tubes connecting steam drums to mud drums. The tubes in the latter case, are closely spaced to provide for the speeding up of the gases to give increased rate of heat transfer by the convection currents.

The steam drums A are connected direct with the lower drums B by the convection bank of tubes, and with the primary bank through the headers C. Each of these upper headers carries a number of tubes which connect to similar headers D placed adjacent to the lower drums on the same side, and also front tubes which connect to headers D on the opposite side of the combustion chamber. The lower headers D are each connected by short tubes to a transverse header, one on each side, and the latter headers have connection with the lower drums for the supply of circulating water to the primary bank of tubes. The steam drums are connected together by tubes above and below the water level, which forms a means of interlinking the two sides of the boiler, in addition to the front tubes of the primary bank. The superheater is located between the primary and secondary bank of tubes, at S.

The illustration shews a combustion chamber equipped with water cooled walls, on two sides only, and with water cooled floor. The water cooled walls consist of a number of vertical tubes joined to upper and lower combustion chamber headers, the upper headers being connected to the steam drums, and the lower of such headers having connection with the lower drums. In this way water is fed to the lower headers from the lower drums, passes to the upper headers *via* the tubes comprising the wall, and thence to the steam drums. The floor tubes are similarly terminated by floor headers having connection with the drums. Thus the lower floor headers are fed from the lower drums, and the rising water flows to the upper floor headers and thence to the steam drums.

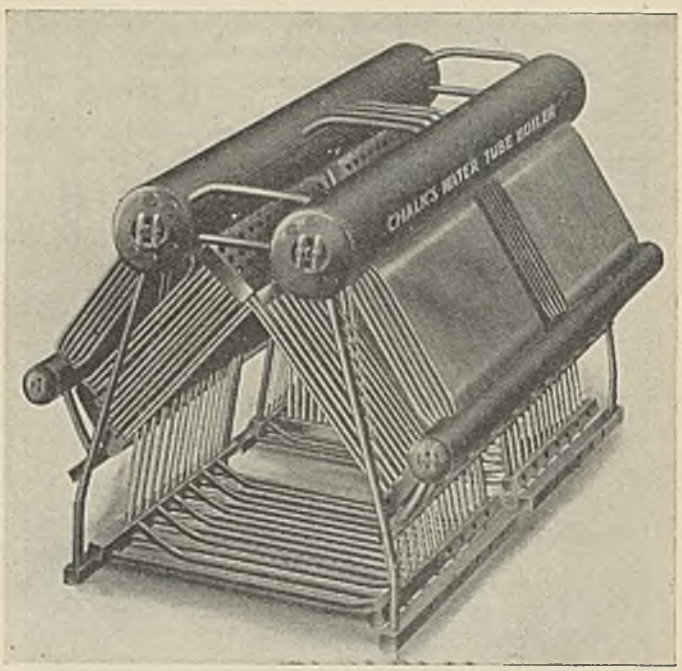

Fig. 2.

In this design there are four fuel burners, the burners being allocated in the front and back of the combustion chamber. In this way the streams of pulverised coal and air are directed towards each other and meet in the centre where a very intimate mixing of the burning particles will take place and produces the turbulent state necessary for good furnace conditions. The gases flow upwards and straight across the heating surfaces of the boiler, without impediment by baffles. The gases then pass to the economiser and finally flow through the air heaters which, it will be seen, are located over the steam drums. The absence of baffles, it is claimed, will reduce to a minimum the loss of pressure head in the flow of the gases over the surfaces, permitting a greater pressure head to be available for creating a high gas speed so necessary for efficient heat transmission at the rear of the boiler.

The circulation in the boiler is such that the water will flow from the steam drums A down the rearmost tubes of the secondary heating surfaces to the lower drums B. A proportion of this water entering the lower drums will return direct to the steam drums through the remainder of the tubes of these banks of tubes, a further proportion will flow to the lower headers to feed the tubes of the primary heating surfaces, while the remainder of the water will flow to the lower wall headers, and lower floor headers, to feed the wall tubes, and floor tubes, respectively.

The boiler was designed for a normal evaporation of 80,000 pounds of steam per hour, and it will be

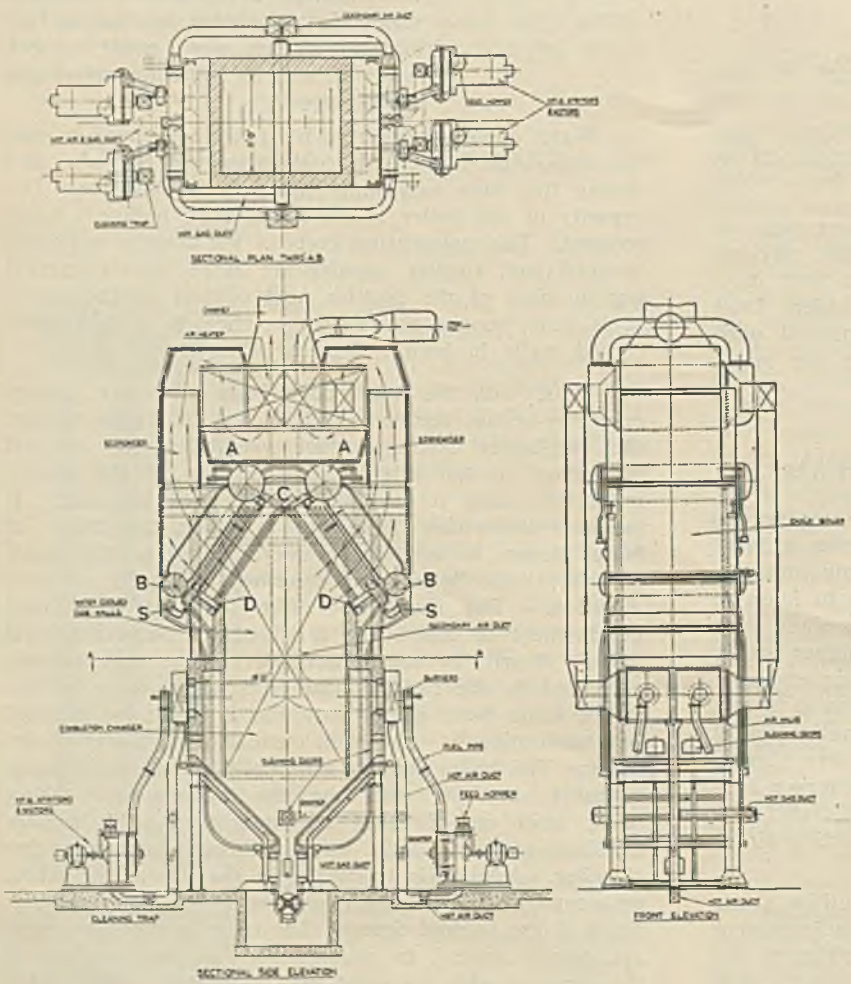

Fig. 1.

seen that the floor space required is considerably less than normal requirements. This, it is claimed, is one of the features of the boiler, and it is brought about by the unique provision of headers in conjunction with drums to accommodate a percentage of the heating surface. The headers are short, and are easily and cheaply manipulated during production. The length of the headers will seldom exceed 3 feet.

The second illustration (Fig.2) shews the boiler designed for marine application and for oil fuel firing. The boiler, in this case, is double ended with water cooled partitions across the centre of the boiler. The boiler will be understood from the foregoing description of the land type, except for one further feature incorporated in the design. This feature refers to the gap tubes, which pass between the tubes of the primary heating surfaces, with their upper ends terminated by the steam drums and the lower ends by the headers to be seen in the lower corners of the combustion chamber. These latter headers also accommodate one end of each alternate floor tube. These gap tubes function to cool the sides of the furnace, and to increase the tube area to radiant heat.

The design gives a very large heating surface on a minimum floor space, with a high percentage of the surface exposed to the radiant heat from the furnace, and every part of the tubes of the boiler effectively swept by the hot gases in virtue of the absence of baffles. The superheater is effectively placed, and the spacing of the tubes of the secondary heating surfaces will ensure that a low gas temperature is reached at exit.

Outdoor End Boxes.

The two illustrations herewith shew the general appearance and details of the construction of a useful

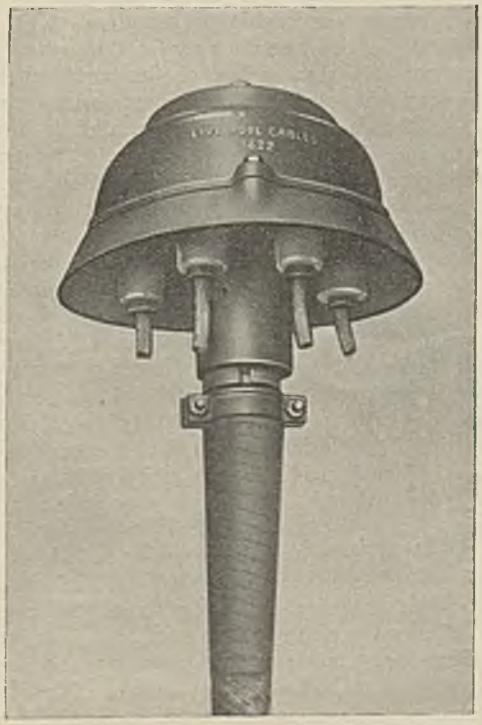

Fig. 1.—Hooded Outdoor End Box.

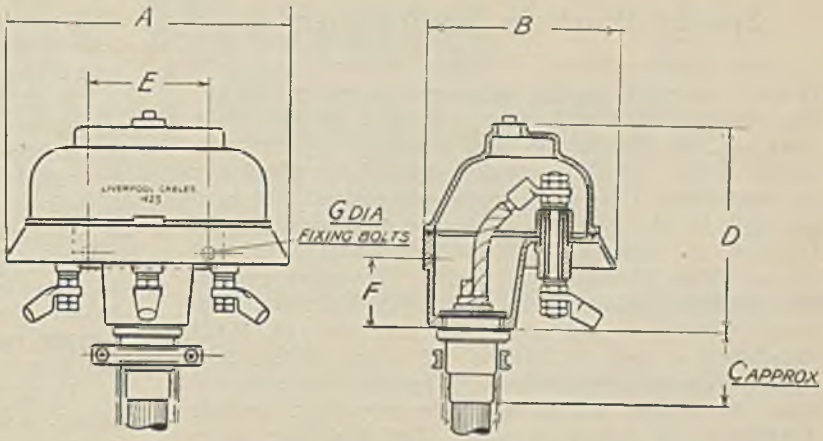

Fig. 2.—Details of the Hooded End Box.

addition to the accessories necessary with overhead distribution services. The hooded type outdoor end box, made by the Liverpool Electric Cable Co., Ltd., is available as standard in two types. In one case the fitting is provided with porcelain insulators containing the rod terminals. The other type is arranged for bare tails to enter the box direct through porcelain insulators. Both types are supplied complete with fittings, wiping glands, sealing compound and armour clamp when required. Pole straps can also be supplied when required and the diameter of the pole should be stated when ordering. The carcase of the box is made from best quality close grain cast iron with a black stoved enamel finish.

The boxes are available as for twin- three-core and four-core connections and for conductor sizes ranging from 0.06 in. to 0.5 in. The limits of general outside dimensions, as shewn in Figure 2, are: A, $12\frac{1}{8}$ in. to $18\frac{5}{8}$ ins.: B, $8\frac{1}{4}$ ins. to $12\frac{3}{8}$ ins.; D, $8\frac{5}{8}$ ins. to 13 ins. according to the number and section of the outgoing cables.

Safety Belts.

Everyone who has had to be responsible for the employment of men working aloft on buildings or poles knows how extremely difficult it is to make those men wear the safety belts which he may provide for their use. The employer requires a belt which is designed primarily for safety, whereas the workman requires a belt which shall not in any way interfere with his free movement. It is for this latter reason that the workman so often declines to be harnessed with any belt at all. The design of suitable safety belts has, therefore, come to be quite a special business, and it is one in which Messrs. A. Hanley of Sheffield have been interested for many years.

The ordinary belt used by men on pole work is a thick trousers strap with hole and tonge buckle and with a piece extra to go round the pole; it has been shewn that a much safer belt is one without buckles and holes but so fastened that a sure locking grip can be secured on the man and round the pole: and which, moreover, provides a belt adjustment which can be made with one hand. This principle has been adopted in the Hanley belts of which several types are available each offering the highest degree of safety compatible with freedom of the workman to do his particular work readily and effectively.

Speedy Work in South America.

The October issue of *The Metropolitan-Vickers Gazette* contains reproductions of a series of twenty-five photographs round which is woven an interesting story of the construction and equipping of the new power station which is rapidly approaching completion in Montevideo, Uruguay. The whole contract has been executed by the Metropolitan-Vickers Electrical Export Co., Ltd., in conjunction with the Administracion General de las Usinas Electricas del Estado. The work covered the complete equipment of the station buildings, with plant, switchgear and auxiliaries, etc., for an initial installation of two 31,250 k.v.a. 0.8 power factor, 3000 r.p.m., 6300 volts, three-phase, 50 periods, turbo-alternators. The station will ultimately be extended to include 120,000 k.w. of generating plant. The total time which elapsed between the commencement of the work on the station, and the starting up of the first 25,000 k.w. set was only sixteen months. This represents remarkably quick work when due consideration is given to the fact that close co-operation was necessary with the various sub-contractors, several of whom were continental firms, and also when it is remembered that the power station site is approximately 6000 miles away, with the corresponding delay in transmit of mails, etc.

In spite of these and other difficulties, the contract was executed within the promised period, and the new station is now, with the exception of a few details, practically complete.

As an example of the nature of the difficult conditions which had to be faced may be quoted the description of how the alternator stators were handled. Each of the two stators weighs 65 tons, and owing to the fact that the wharf cranes were not large enough for handling pieces of this weight, a floating crane had to be employed. This crane carried the stator from the ship-side to the wharf adjacent to the power station site, where a special railway truck had been chartered. The stator being loaded on the truck was moved into the loading bay in the turbine house ; the final lift was by means of the turbine house crane which lowered the stator into its permanent position on the foundation block.

This operation was successfully carried out in January last, and by the end of March the first turbo-alternator was practically completely erected with all its accessories.

One of the photographs shews a view of the complete station taken on March 30th, 1931, and this when compared with another view shewing the turbine house excavation work only six months earlier, represents in a convincing manner the rapid strides which were made during the construction period. Similar advances in all other sections of the work contributed to the general satisfaction felt in completing the work well within the contract period.

Automatic Load Indicators for Cranes.

A new Home Office Order came into force on November 1st, in connection with the Building Regulations in respect of cranes used in certain building operations having a fixed jib or a derricking jib. This Order, with certain date reservations, calls for an Automatic Indicator to be fitted to all such cranes of a type approved by the Chief Inspector of Factories. It is laid down in the Order that all such indicators shall shew clearly to the driver, or person operating the crane, when the load being moved approaches the safe working load of the crane at any inclination of the jib, and shall also give an efficient sound signal when the load being moved is in excess of the safe working load of load of the crane at any inclination of the jib.

It is claimed by Vickers-Armstrong Ltd. that they are makers of the only indicator on the market that has so far been approved by the Chief Inspector of Factories for compliance with this Order. Known as the Vickers-Nash Safe Load Indicator, this device ensures safe loading of jib cranes irrespective of the doubtful judgment of the crane driver or his "slinger" as to whether a given lift may be safely undertaken. It will be understood further that, in addition to the assurance of safety, a crane can be utilised with confidence to its capacity and thus a greater tonnage per day can be obtained.

In the Vickers-Nash indicator the load is weighed against a spring reaction ; the resistance of this spring in turn is varied by the angle of the jib, but since the safe loads do not vary in "direct" proportion to the radius, the mechanism has to take into account the crane makers' permissible loads at the various jib radii. The indicator is of an extremely robust and "fool-proof" nature, and yet such as to give accurate readings.

An eccentric sleeve is interposed between the jib head pulley and jib head spindle, and is set in such a position that the weight on the bond rope tends to turn the eccentric. Fixed to the eccentric is a tension arm which is connected to a spring inside the indicator case by a rod which is led down the jib through one or more roller guides. The jib head pulley is carried upon an eccentric, which in turn is mounted upon the jib head spindle, ball or roller anti-friction bearings being used.

To the indicator proper are taken two rods, the upper tension rod from the jib head eccentric, and the lower rod pivoted to the base of the crane. These actuate the indicator as follows :—The tension rod passes through a compression spring in the case, so that the spring is compressed by any weight on the bond ; this compression spring does not abut against a fixed point, but against a trunnion carried upon a rocker, Movement of this rocker, therefore, has the effect of varying the stress in the spring.

The lower rod is connected to a cam which is pivoted within the case ; this cam is so cut that its profile gives the correct relationship of safe load to jib radius as established by the manufacturer of the crane. As the jib is raised, this cam moves on its pivot, the rocker is tilted, and the stress in the compression spring increased, so that a heavier load is needed to bring the pointer to the danger point. Conversely, lowering the jib moves the cam in the opposite direction, the rocker lessens the stress in the compression spring, which thereby becomes more sensitive to the lighter load permitted at the longer radius, so that a lighter load can bring the pointer to the danger mark. Thus the whole action is entirely automatic, and the margin of safety or approach of danger is correctly indicated in accordance with the ratings established for the particular crane.

The indicator can be arranged in several forms. The one normally supplied consists of a plain pointer and a scale. The "safety" portion of the scale is painted green ; the "maximum" mark is white and the "danger" portion is painted red. Means are provided by a pointed mechanism operating an electrical or mechanical alarm bell. In addition to the indicator, a sealed "tell-tale" is fitted so that, in the event of an accident, it can be ascertained whether or no the crane has been overloaded at any time, and if so, to what extent.

Vickers-Armstrongs have obtained the sole manufacturing and selling rights of the indicator for Gt. Britain and Northern Ireland, and it is being produced at their Dartford Works.