The Mining Electrical Engineer.

OFFICIAL JOURNAL OF THE ASSOCIATION OF MINING ELECTRICAL ENGINEERS
EDITED BY E. DINSDALE PHILLIPS.

VOL. IX. JANUARY, 1929. No. 100.

The Call of the New Year.

From time to time most men are disturbed by the uneasy presentiment that things are too settled and restful: periods when one would seem to become conscious that the even tenor of the way threatens degeneration by stagnation. Perhaps it is that the negative symptom of having nothing to grumble about is a true sign that something is going wrong. Be that as it may, the normally observant person learns very early in life that in little or great affairs there is never any standing still. However slowly or quickly the elusive element Time, as we try to understand it, may be shaping any matter or destiny, there is ever either the free running up to growth or the drifting down to decay.

Such is an Elemental Law. Many of our readers will have discovered themselves in this mood with the advent of the New Year. For in those particular interests which are primary to the friends of this Journal, the warm sap of progress has been too long stayed in a seemingly endless cold winter of industrial depression. Whilst commending the solace of sympathy, heartfelt and altogether sincere, so universally extended to those in actual want, we would urge those who have been "hit by bad trade,"—the majority who yet manage to carry on—to add solid weight to the sentiment of their expressions of concern.

The National Call voiced by the Prince of Wales has been heard throughout the land. Make the response worthy of the need and of its gracious spokesman. Such is the first duty of the New Year.

After attending to that immediate call, let those who have conscious qualms of stagnation awake to the fact that greater effort is demanded of them, and be up and doing.

The Lead from the Ranks.

It is a common mistake of the rank and file of humanity to believe that they have no influence in directing the affairs of industry; whereas in reality they collectively were the source of all the great beneficial changes and developments which ever took place. It is only from them, and assisted by them, that future improvements will come into being and be made fully operative. They can break or make trade.

Should this simple truth not be perfectly clear to anyone we would suggest to him that he scrutinise his work-place. He will see much more than he ever saw before when he searches with deliberation for better method and better plant for his particular job. When the majority of workmen exercise this critical vision and so become actively progressive in aim and endeavour, the leaders of industry must of necessity, and automatically as a natural consequence, provide facilities annd adopt policies in keeping with the progression.

To make this excellent quality of the individual worker effective it is desirable that the views and ideas be regularly collected, fostered and encouraged by the individuals meeting together for the interchange of observed facts, knowledge and opinion. This aggregation, by clear reasoning and well informed judgment, gives weight and puts true values to the progressive measures thus brought into the open light.

We know that there is nothing new in this suggestion: we know that the getting together of men in regard to common interests has been the making of history ever since man had any history: but we also know that old axioms and truths are easily overlooked in the presence of crowding novelties and the pressure of detail business. This then is meant to be a gentle reminder to exercise the broad outlook and a plea for renewed will and endeavour on the part of every worker in the New Year.

Concerning Ourselves.

This issue of **The Mining Electrical Engineer** is in the nature of a "special number" for several reasons. Perhaps the least of those reasons is that this happens to be our one-hundredth edition, and we are prompted to make the fact known—with a sincere acknowledgment to those friends who have helped us to build up and maintain this Journal, as well as in the hope that their increased help will enable us to give still better service to the mining electrical industry with succeeding years.

Official Grading of Mines' Engineers

It just happens that our number one hundred synchronises with the birth of New Year; but the period also coincides with an exceptional phase in the affairs of mining electrical engineers. Already in these columns attention has been directed to the current enquiry of a Governmental Committee in regard to the qualifications and education of engineers and other technical men engaged in colliery work. That this enquiry must be of the greatest interest and portent to our readers, and particularly to members of the Association of Mining Electrical Engineers, is obvious. Nor is it too much to say that the Association, with all it does and all it stands for, will surely be introduced with some considerable weight into the deliberations of the Committee of Enquiry. It is understood that the Association will, in fact, submit evidence to the Committee.

In view of this important official move we feel sure it will be generally agreed that the present time is opportune for spreading throughout British colliery circles, leading facts concerning the Association of Mining Electrical Engineers. Special articles and contributions by engineers who have long been active workers in and for the Association, and whose names are well known wherever electrical mining work is considered, are published herein. An exceptionally large edition of this issue of **The Mining Electrical Engineer** will ensure the carrying of the message of the Association into every important colliery in the Kingdom.

The Value of The A.M.E.E.

In the course of its eighteen years' existence the Association has, not unnaturally, been occasionally the butt of criticism. When its foundations were being laid there were those who said that of technical associations there was no end, that already electro-technical matters were well covered by existing societies, and so on. The records of the A.M.E.E. prove that, at any rate, there was ample scope for the work of an independent association to promote and develop interest in the highly specialised field of electrical engineering in mining.

Then, as the A.M.E.E. grew and prospered, there came the criticism that the Association should be discredited because its membership list was thrown open to admit those who were not actually engaged in electrical work in and about mines. Whatever may have been the motive behind this attitude—and we do not seek to be uncharitable—it quickly subsided in the light of publicity. For of a surety the deliberately wide door of membership has fully justified the intentions of those who stood by this principle. In effect this policy has proved to be one of the most meritorious. The A.M.E.E. has thus come to be recognised as the readiest and most accessible means of bringing practical working mining electricians and engineers into useful personal contact with mining interests of the scientific and commercial kinds, to the very great advantage of all concerned.

It is customary to speak of scholastic attainments as "education," but it is none the less true that, in engineering in particular, there is educational knowledge to be imparted by the skilful craftsman to the academic scholar, as there is the other way round. It is the best of both forms of proficiency which gets things done properly.

So it is that the Association of Mining Electrical Engineers has come to be considered as a particularly effective educational adjunct of the national mining industry. Electrical machine users, designers, manufacturers, scientists, commercial men, mines' managers and owners; juniors and experts—all these come together in the ranks of membership and at the meetings of the Association. The advantages accruing to the individual and to the industry are self-evident. Those who may still be dubious on this point should look through the volumes of this Journal and learn that college professors, mines' inspectors, consultants—and working electricians—have regularly provided invaluable papers to the Association and have freely collaborated in discussion.

The A.M.E.E. and Education.

This catholicity of the Association of Mining Electrical Engineers is so markedly successful that its aims and accomplishments might almost be crystallised into the word "education." Then again, and as being a measure devised on orthodox educational lines, the Association founded its Examinations and Certificates system for the express benefit of its junior members as well as to cultivate a class-standard of mining electrical engineers, competent and capable. By this step alone the Association rendered very great service to the electrical and mining industries as a whole.

The A.M.E.E. Certificate is a tangible proof of the competency of its holder: it provides the colliery manager with one definite means of judging the attainments and qualifications of some candidates for places on his electrical staff. It brings the somewhat vague official term, "competent person," into more clearly defined and understandable limits. Moreover, this examinations system induces in the practical electrician and the junior worker the incentive to study and the will to progress: to them the Certificate is something definite to work for, and well worth the working for.

Where National Education is Weak

It is very desirable that everyone should be cognisant of the great educational value of the A.M.E.E. at this present time; for there are signs all around that our people are quickening to the realisation that the national system of general education is far from perfect. It does not help sufficiently towards greater happiness and prosperity—which, after all, in a few words is the sole aim and object of Education. Some would say that secondary and higher education centres ought to be as numerous and widespread as are the elementary schools. The present system, with its distinct demarking line between the elementary and higher grade schools, makes such a multiplicity of units financially impossible. Alternatively, others recommend that the "leaving age" of the elementary school be advanced: presumably the extra two or three years would mean the elementary school encroaching on the preserves of the secondary school—a shattering upset of present ideas.

There are, however, two prominent weak factors which will have to be corrected. One is that the degree of finish at the elementary school does not enable the pupil to take up study at the technical school. The other weakness is that, of the multitude which passes each year from the elementary schools, only a small fraction are so placed in the geographic, industrial, or economic senses that they can continue study in either a secondary or technical school. To discuss this matter further would be outside our province, but it has been necessary to go so far in order to bring out the fact that mining electrical and mechanical engineers are exceptional sufferers, as a class, under these imperfections of the national system of education.

Under these circumstances, therefore, whatever the Association of Mining Electrical Engineers is doing to help and encourage the engineer-worker of the mines, be it much or little, is of exceptional value to the individual and to the industry.

It is not difficult to see how this beneficient work of the A.M.E.E. could be greatly enhanced and developed as its strength of members, its prestige and its available means increase.

As things are at present the technical schools, even when they are conveniently near at hand, are not open to take the young workers who "finished" at the elementary school and went straight to work. A further few years of general school work at the local night classes, having no attractive bearing upon the technical side of the young worker's job, is distinctly repulsive to him. Why should he, who having turned fourteen years of age and is so considered fit to work for his living, not have facilities for entering immediately into a technical school?

Whether this obvious weakness of the national system of education may be corrected by any modifications such as those which have been indicated, the great truth of the matter is that the A.M.E.E. has been the saving in an educational sense of many of those young workers.

It should be emphasised that this has all along been a most important part of the general policy of the Association. Working engineers of the mines, juniors and seniors, are the men primarily to be served. Student members are a distinct class entering at a pocket-money subscription. There are ten branches and six sub-branches, in effect sixteen active working centres of the Association distributed over the coal-fields of the country. Wherever there is a local nucleus of men keen to use the Association, meetings are held in that place, and ultimately a branch is established.

Every branch controls its own funds, elects its own officials and directs its own affairs. The organisation of the Association is remarkably efficient and progressive. The full member's subscription of one guinea a year brings it within easy reach of the men it is intended for and it indicates also the economy of its administration.

So it has been enabled to bring out and educate, in the really valuable economic and technical way, very many who would never have returned to school. However limited the purely scholastic attainments of a man, above the minimum of a sound elementary acquaintance with the three Rs, it is hardly possible for him to be a regular member of the A.M.E.E. without his acquiring much knowledge of the kind most valuable to him in business.

The Call of The A.M.E.E.

Here then is another call of the New Year to those interested in mining electrical engineering. Think over the work of the A.M.E.E. and add your weight to its policy of progress; by so doing you will add to your effective value in forwarding the great national mining and electrical industries.

NEW CATALOGUES.

DUBILIER CONDENSER Co., Ltd., Ducon Works, Victoria Road, North Acton, London, W. 3.—The List No. 928 is a profusely illustrated catalogue which deals fully with the Dubilier Condensers and Radio Products. It contains much matter of technical interest in regard to the practical application of the specialities shown.

BABCOCK & WILCOX, Ltd., Babcock House, Farringdon Street, London, E.C. 4.—The booklet No. 919 dealing with the "Babcock" Low Temperature Coal Distillation System will be read with general interest in progressive mining circles. The illustrations and data of results and process are exceptionally clear and valuable.

Calendars, Etc.

Acknowledgments are tendered to the following firms for seasonable useful gifts: C. A. Parsons & Co., Ltd.; The Anglo-Swedish Electric Welding Co.; Cambridge Instrument Co., Ltd.; Enfield Cables, Ltd.; Crompton-Parkinson, Ltd.; Anderson, Boyes & Co., Ltd.; Geo. S. Ikin & Son, Ltd.; General Electric Co., Ltd.; Simplex Conduits, Ltd.; Ruths Steam Storage, Ltd.; British Insulated Cables, Ltd.

"The Association."

FRANK ANSLOW

(President of the Association of Mining Electrical Engineers).

IT is a time-honoured convention of our Association that the President should visit each Branch during his term of office; a task of some magnitude but also one which carries with it many compensations, not the least being the cordial reception and attentive hearing accorded him wherever he goes, and which provides a source of many permanent pleasurable recollections for his later years. It is expected that when visiting a branch the President shall deliver an address and I have taken the view that this address should not be too formal but should rather be a homely talk upon the interests of the Association in general and the Branch in particular. It is not always possible to say something new at each visit; on the contrary, in referring to the activities of the Association, a certain amount of repetition is unavoidable and indeed necessary and desirable. Having this in mind led me to suggest to our Editor that he should allow me a little space in this issue of the Journal to refer briefly to a few matters which I regularly bring before the Branches, and which cannot reasonably be printed over and over again in the several reports of the meetings of those Branches.

My meetings with the North Western Branch in July and with the Midland Branch in November have been fully reported in the Journal, so I start with a reference to meetings with the West of Scotland Branch and the Warwickshire and South Staffordshire Branch in December . At these meetings it was possible to refer to matters which are actively engaging the attention of General Council at the moment and particularly to the invitation received by the Association to submit evidence for the information of the "Departmental Committee of Inquiry into the Qualifications of Colliery Officials" and to submit suggestions for facilitating education in mining districts. In this we have a splendid opportunity of showing what our Association has accomplished in the past and how it is proposed to consolidate and extend its usefulness in the future. Our view, expressed in the right spirit, and in keeping with the aims and objects of the Association, cannot fail to be helpful in any steps towards securing a higher status for the Colliery Engineer and Electrician. With regard to better facilities for education in colliery districts, the General Council have already taken steps to ascertain what can be done in this direction by co-operation with existing educational authorities, with a full appreciation of the great sacrifice in time and expense which is frequently required of the man seeking necessary educational instruction.

At both these meetings I took the opportunity of referring to the continued depression in the coal industry and stressed the consequent need for economy in coal production by the more extensive use of electricity, particularly underground. It is perhaps beyond our vision to see how and by what method the coal industry is to regain its prosperity, but one fact stands out clearly and that is, that our Country still contains vast quantities of coal which have to be won; and that, in its winning, electricity will play a great part. Thus in future our collieries will be equipped for intensive machine working, and particularly intensive electric machine working, calling for electrical plant of the highest standard, and operated upon the most economical lines. The electrical equipment of a modern colliery, consisting as it does of an extensive system of shaft cables and distribution cables and switchgear, offers many possibilities for economies here and there, which together with savings in running costs which may be obtained by close attention to motors, gearing, and the plant they operate, though small individually, collectively assume important dimensions.

It is to the advantage of all concerned that our Colliery Engineers and Electricians should take the fullest opportunity .of the facilities offered by membership of the Association to obtain an ever-increasing knowledge of their craft.

My meeting at Kirkcaldy with the East of Scotland Branch, also in December, was of a totally different nature, as the meeting had been convened with the object of stimulating and reviving interest in the Branch which has been passing through troublous times; and here I would like to record an appreciation of those Branch Officials who have so loyally stood by the Branch and so zealously struggled to keep it active; to congratulate them on the success so far attained, on the prospects for the future and an excellent syllabus for the remainder of the Session.

At the meeting were many who had no knowledge of the aims and objects of the Association and who had come to learn something of them. The experience of outlining our aims and policy with such an audience was extremely interesting and valuable, and I found in it a new appreciation of, and a renewed faith in, the objective and the power of the Association, given a due measure of support, to bring its intentions to fruition. I, therefore, record my impressions of the meeting in the hope that, not only will it help those whom we hope to welcome into membership, but also that it will be useful and interesting to some members who may not be fully alive to the advantages of membership.

In doing so, it is well to keep before us sections (a) and (b) Paragraph 3 of the Articles of Association, which describe the main objects of the Association, and which read as follows:

"To consider means for minimising the risks attending the application of electricity to the industry of mining, and to promote the adoption of approved methods and devices tending to increase safety."

"To promote the general advancement of Electrical Science in its application to the industry of mining; to facilitate the exchange of information and ideas on this subject amongst the members of the Association and otherwise; and generally, to extend the experience, increase the efficiency, and elevate the status, of those engaged in such applications."

A consideration of these paragraphs brings forward into clear relief the important facts:—

1. That the Association is not in any sense a Trades Union.

2. That it is a Scientific Society designed to attain its objects on a mutually educative basis.

3. To attain these objects the conditions of membership are made sufficiently wide to attract and encourage members from the whole field of those interested in the Mining Industry

A recognition of these features of the Association has enabled Colliery Managers, Consulting Engineers, and members of Manufacturing Firms to co-operate with the Mining Electrical members who are directly concerned with the installation and maintenance of plant in the mines, to the well-being of the industry. Thus Colliery Managers have, by their practical support in becoming members, by contributing papers and taking part in discussions, and by encouraging those under their charge to join the Association, contributed largely to its success Also Consulting Engineers have never hesitated to place their time and experience at the disposal of, and to the interests of, the Association. Manufacturers have contributed papers of value and also assisted by the loan of lantern slides, illustrations, and data, to assist, in particular, colliery Electrical engineers in the writing of papers; and last, but not least, recognition is due to Patron Members and Colliery Owners generally for their appreciation of the work of the Association and the help they have given. It is pleasing to remember that many prominent representatives of Colliery Owners are numbered amongst our Past-Presidents and we look forward to similar representatives in the immediate future.

With regard to the advantages to the Colliery Electrician Member, these must largely depend upon the interest he is prepared to take in the activities of the Association, but it is quite clear to see that these are available in the meetings which are held monthly during the session at which papers of direct interest to him are read and discussed. By attending these meetings, and particularly by taking part in the discussions, he has opportunities of improving his knowledge and his capability of expressing and applying this. Our Journal, *The Mining Electrical Engineer*, which publishes the Proceedings of the Association, together with articles of general information relative to mining electrical plant, is in itself a complete book of instructions and reference.

The Editor of the Journal—knowing that it is not at all uncommon for engineers to shrink from writing for the Press or speaking to an audience, because of the innate modesty of inexperience—has always insisted that it is his duty and pleasure to safeguard the writer or speaker in regard to the printed record.

It is important to keep in mind that, not only does the Association afford facilities to its members for acquiring a high degree of proficiency in Mining Electrical Engineering and thus enabling them to qualify for the higher positions and higher awards available in the industry, but by its system of examinations it is in a position to show that this knowledge has been acquired. A certificate is issued to all members successfully passing the examinations, which is of real value and is held in high esteem by the great body of Colliery Managers whose duty it is to appoint competent Electricians.

Every Branch should induce as many of its Colliery members as possible to sit for these examinations. The number who so far hold the certificates is not as great as might be desired, which is at least partially due to the difficulty of obtaining the necessary education in mining districts. It is hoped that the endeavours which are now being made to improve the facilities for education will result in greatly increased numbers being willing and able to take the Examinations of the Association.

In concluding this little message I would say that I, personally, have every confidence in the future of our Association and that, when the coal industry emerges from its present troubles, it will improve and extend the useful work already accomplished. In the meantime, the industry may be assured that our members, individually and collectively, are doing all in their power to "carry-on" in the present depressed conditions.

I wish all our members and our many friends all Happiness and Prosperity for the New Year.

The British Industries Fair.

Much greater than ever will be this year's British Industries Fair, to be held concurrently in London and Birmingham from February 18th to March 1st next. The Birmingham section will cover the heavier electrical and general engineering interests in which some 700 exhibiting firms will combine. The Programme of Official Visits to Birmingham includes:—

February 22nd.—Conference by South Midland Area Committee of the British Electrical Development Association. Luncheon to Incorporated Municipal Electrical Association, Incorporated Association of Electric Power Companies, Provincial Electric Supply Association, British Electrical Development Association, Municipal Tramway and Transport Association, Inc., Tramways and Light Railways Association.

February 23rd.—Luncheon to Electrical Power Engineers' Association, followed by Conference. Tea to South Midland Students' Section of the Institution of Electrical Engineers.

March 1st.—Luncheon to Institution of Electrical Engineers, Association of Consulting Engineers, Inc., Association of Supervising Electrical Engineers, Electrical Contractors' Association, Inc., Electrical Contractors' Association of Scotland, Electrical Wholesalers' Federation, Ltd., Electrical Merchants and Manufacturers' Association, Illuminating Engineering Society, Association of Mining Electrical Engineers.

Tea to the Electrical Association for Women, Birmingham and Midlands Branch.

A Short History of the Association of Mining Electrical Engineers.

A. B. MUIRHEAD*

IT is with feelings of pleasure tinged with regret that I accede to the request of the Editor to write a short article on the history of our Association—pleasure because of the many happy memories that cling to the story of its rise and its progress; regret because of the fear that my limitations as a writer may detract from the value of the story.

The Association of Mining Electrical Engineers was formed in the year 1909 after some months of pioneer work on the part of a few men who were intimately connected with the mining industry, and who felt that the rapidly extending use of electrical power in its applications to the industry pointed to the necessity of some steps being taken to promote the general advancement of this science; and to extend the experience, increase the efficiency, and thus elevate the status of those engaged in such applications.

It is occasionally said, and it may be admitted that there is some truth in the saying, that the Scot does not readily admit strangers into the inner circle of friendship, unless their credentials can bear the strictest scrutiny, but the early history of our Association bears witness to the fact that the "Predominant Partner" can at times show the same caution without troubling too much about the credentials; for it was our experience in the the early days of our career that many of the leading lights of the mining industry looked upon us with disfavour. There were rumours of a tendency to Trade Unionism and so the Prophets who believed in and had the temerity to forecast the ultimate success of the new Association had, in the course of their travels in the mining districts, to face the modern form of an ancient question—" Art thou he that troubleth Irael "

A section of the Electrical Press found a text on similar lines sufficient to provide material for a few columns of a condemnatory nature. A story could be written of a dinner arranged by some of the Members of the Council of the Association of that time to enable them to meet the sub-editor of a leading journal. During the evening he had the truth regarding the aims and objects of the Association pointed out to him, to his ultimate conversion.

The "Kindred Associations" of those days for the most part kept us at a distance proportionate to their sense of dignity. "There was no room for another technical Association" was their excuse. And thus we started out to plough a lonely furrow.

The Association accepted the position with good grace. It had the gifts of youth at its disposal,—strength and vigour and enthusiasm. Its members set themselves resolutely to the task of doing all in their power "to promote the general advancement of Electrical Science in its application to the Industry of Mining", with the the result that many prominent colliery owners, general managers of colliery companies, managers of collieries, and also manufacturing and consulting engineers, joined the membership and rendered invaluable service in bringing the Association into the prominent position it now occupies.

Those of us who have been identified with the work since its inception look back with gratitude to Capt. Cheeseman and Mr. Harold Jeans of *The Iron and Coal Trades Review* for the great service they rendered in publishing our proceedings in their Journal. We were not, and could not hope to become, a wealthy organisation. We were out to help colliery electricians by providing means for the exchange of information and ideas on the subject of electricity as applied to mining, to help them to extend their experience and increase their efficiency, and we had to keep our annual subscription at a low figure to suit their standard of income, therefore the reasonable terms upon which *The Iron and Coal Trades Review* published and distributed our proceedings proved to be a material asset during our early years. Even with this help, experience proved that what we gave to our members approximated too nearly to what we received by way of subscriptions and a stage was reached when the financial position became critical. A committee was appointed in 1915 to examine the affairs of the Association and to formulate proposals whereby its finance would be placed on a secure basis and the organisation improved. The report of this Committee was adopted by the Council, with most satisfactory results.

Our progress was so well maintained under the new arrangements that it was decided in 1920 that the affairs of the Association were sufficiently consolidated and that its membership had become sufficiently large to justify the publication of its Proceedings in the form of a monthly Journal. A Publications Committee was formed including Mr. W. T. Anderson, now a Past President, as Convenor, and Mr. Frank Anslow, our present President, and with the able assistance of Mr. E. Dinsdale Phillips, our Editor, their labours resulted in the appearance of the first number of *The Mining Electrical Engineer* in October, 1920.

The Mining Industry has passed through a time of severe trial and serious difficulty in recent years—a period of hardship to all dependent upon the industry—but it is indicative of the usefulness of the Association that the number of members on the roll at the end of the financial year March, 1928, was 1981, this being only a a slight reduction in the total number of Members in any previous year: since then the membership has steadily increased.

* Mr. A. B. Muirhead was President of the Association, 1922-23; he has been convenor of the Advisory Committee since its formation, and throughout he has been one of the most active workers in directing the affairs of the A.M.E.E.

The Association came into being at a time when the use of electricity in mining was advancing at a remarkable rate; it has lived through periods of strain and stress of an intensity unknown to earlier generations, and it is now entering a stage of progress in the development of the use of electricity at the coal face hitherto unthought of.

This development is intended to and is expected to enable the mining industry to produce coal at a price which will enable it to compete more fairly in the world's markets and the future history of the Association is bound up with this development.

It follows that the increased and increasing use of electricity at the coal face will provide employment for an additional number of skilled electricians, therefore to the many who are qualifying for such positions and to the large number of colliery electricians who are not, so far, members of the Association of Mining Electrical Engineers, I would like to be permitted to give this message—that the history of this Association teaches him that hath ears to hear, and eyes to see, that within its ranks he can find that which is not only helpful but also of first importance to him in becoming fully qualified for, and a master of his job.

Electric Coal Cutters: Official Recommendations.

In the form of Circular No. 31, dated 12th November last, the Mines Department issued an important letter of warning and advice by the Chief Inspector of Mines. Essentially the publication reads:—

I wish to call attention again to the accidents which occur from time to time through ignitions of firedamp attributable to the use of electric power at or near the coal face.

These accidents almost invariably have two features in common, viz.:

(*a*) A temporary and, generally, local deficiency in the ventilating current, together with failure on the part of the officials in the area directly affected to detect that deficiency in time or to appreciate its probable consequences; and

(*b*) A coincident defect in the flame-proof enclosure of the electrical equipment, or some equivalent defect in the accessories designed to prevent open sparking.

1.—*Ventilation.* In several instances the working of coal cutting machines in fast ends of longwall faces where ventilation was either quite inadequate or totally absent, has resulted in explosions of fire-damp not only in seams which were admittedly fiery, but also in seams which, prior to the accident, had been considered comparatively free from firedamp.

The necessity for ventilating thoroughly the fast sides of machine faces has been emphasised again and again in the published reports of H.M. Inspectors. I emphasize it again now. I disapprove of reliance being placed under such conditions upon "leakage through the pack" or similar expedients. I deprecate also the use of auxiliary fans and the like, run intermittently to "clear the district."

It is not always sufficiently appreciated that the use of coal cutting machines is likely to result in the emission of more firedamp than is the case under hand working conditions in the same seam, if only because fresh coal surfaces are much more rapidly exposed by the former process than by the latter.

Good ventilation is always necessary, but it is doubly so in machine-cut faces. It is essential to ensure not only an ample and constant general ventilating current, but also that from hour to hour under the changing conditions the details of bratticing are kept right and all possible steps are taken to guard against the temporary accumulation of even a small quantity of inflammable gas.

I ask all managers concerned to impress this second point on their firemen and deputies and to consider seriously, according to the conditions of the mines in their charge, whether the ordinary two or three inspections per shift by the deputies are sufficient in machine-mined districts.

2.—*Defects in the Electrical Apparatus.* These can be classified under two heads, viz.:

(1) Imperfection of design;
(2) Lack of proper maintenance.

The first sometimes contributes to bring about the second, but the evidence is that neglect to maintain the apparatus in its designed condition of safety is the usual contributory cause of the accident.

One of the commonest defects is the loss or omission of screws from cover plates, whereby an opening is left into a switch box or some equally dangerous part of the apparatus.

An even more common, but less obviously dangerous defect, results from insecure fixing of cover plates where screwed stems have been broken in the hole. Sometimes these are not replaced and sometimes they are unskilfully drilled out with resulting damage to the thread.

Automatic interlocks, to prevent the withdrawal of the plug while current is flowing, are not universal and are sometimes inoperative, and few of the commoner types of plugs in use can be regarded as flame-proof even with such an interlock.

To secure greater efficiency and uniformity in the safety features of design of electrical machinery I suggest that the following principles should be regarded as essential in flame-proof enclosures, viz.:

(*a*) No unbottomed screw holes through the walls of the enclosure;

(*b*) Some device, such as a spring washer or a lock nut, to check the tendency of screws to work loose under vibration;

(*c*) No unshielded projecting screw heads nor, in case of movable machinery, projecting edges of cover plates which may be caught and displaced;

(*d*) No drain plug holes or other similar openings so placed that they cannot be readily inspected;

(*e*) No connecting passages between separate parts of the enclosure;

(*f*) A terminal box, for the external circuit connections outside the flame-proof enclosure;

(*g*) A flame-proof plug and socket coupling, such as the B.E.S.A. type.

I ask that these requirements should be definitely specified by mine owners in ordering all new equipment, and that steps be taken at all mines where this has not already been done to modify existing equipment to comply with items (*a*), (*b*) and (*g*).

The work of inspection and repair should be entrusted only to trained mechanics, who should receive special instructions to enable them to recognise defects that may result in open sparking. It is too much to expect a coal cutting machine-man, or a fireman, or even a mechanic uninstructed in the principles of flame-proof enclosure, to recognise defects in the equipment which, although they may seriously impair its safety in the presence of inflammable gas, may have no effect at all upon its ordinary working efficiency.

A.D. 1828—A.D. 1928: A Contrast in Mining Methods.

S. BURNS, M.I.E.E., M.I.Min.E.

THE system of high pressure distributing networks owned and operated by the Newcastle-upon-Tyne Electric Supply Company and its Associated Companies embraces the whole of the Northumberland and Durham Coalfield, and so it is interesting alike to those engineers who study the economics of the problems that are presented in the generation and transmission of power supplies for collieries and to those who more particularly are concerned with the benefits likely to be derived where a colliery takes full advantage of the supply afforded.

The trend of development is towards intensive machine-mining and as considerable progress along these lines already has been made in this electrified area, it may not be out of place here to contrast old with modern working methods and to dispel, if that be possible, the popular misconception that our mining affairs are least competently directed by those whose whole time and thought are devoted to that work. A convenient plan is to describe two imaginary tours, the first presumed to be made in what occasionally are referred to still as "the good old days"; the second to be undertaken at the present time. Both tours commence (and eventually end) at the coal face, but they are otherwise notably dissimilar, an important difference being that the working conditions to which attention will be directed at points here and there along the routes to be followed, are nowadays immeasurably more humane than once they were.

THE FIRST TOUR: A.D. 1828.

Suppose we are assembled near the face in a typical English colliery on a day early in the nineteenth century. If the pit is well equipped we shall each be furnished with a Davy lamp, but it is not improbable that the only source of illumination will be a train of sparks emitted by a steel-and-flint mill, strapped to the leg of a youthful worker and operated by him to the accompaniment of a grinding screech that is exasperating and continuous.

When our eyes are accustomed to the semi-darkness we shall notice that the pitman is working in cramped surroundings, and as apparently there are still those who imagine that in the process of winning coal by hand all one has to do is to strike indiscriminate blows with a pick upon a vertical face of coal, it is worth while considering for a moment why these cramped conditions should be the rule.

The coal measures with which most of us are acquainted usually are so stratified that the planes of the vertical cleavage faces are at right angles. As a rule the bord cleat is pronounced and is continued into roof and floor; the end cleat ordinarily is less sharply defined and seldom passes into the stone strata. Consequently it is comparatively easy to win coal by hand provided the working face is advanced in a direction at right angles to the bord cleat, or "bordways," as it is called, but with the accompanying risk of an insecure roof, and difficult to advance in an "endways" direction, though in that event a sound roof is almost assured. A hundred years ago the art of underground survey was imperfectly understood and roof timbering practice was at a rudimentary stage; therefore the pitman was obliged to work by circumscribed method. He avoided unnecessary exertion by hewing "bordways" as often as

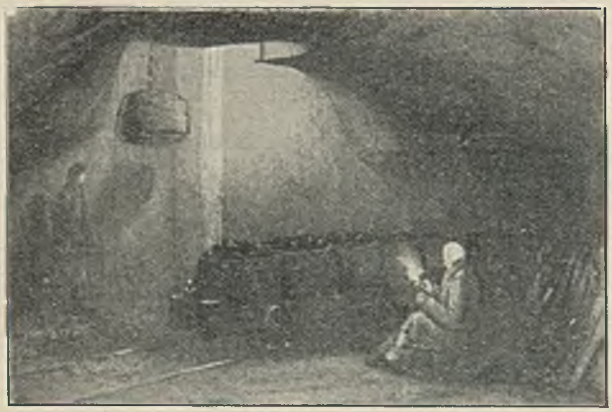


Fig. 1.—Bottom of the Shaft, Walbottle Colliery.

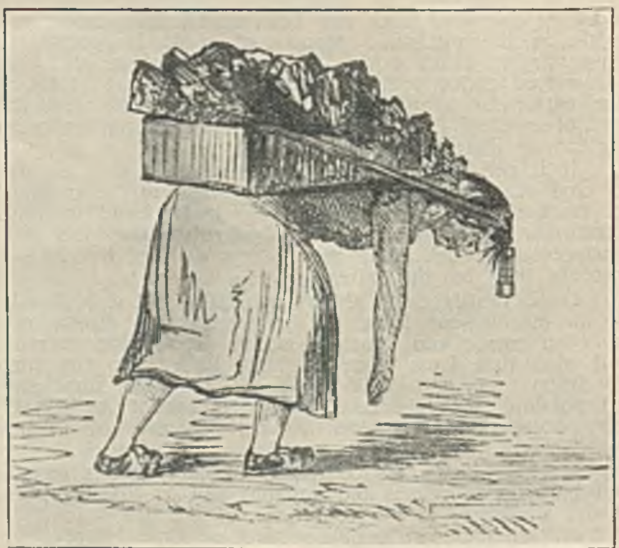


Fig. 2.—A Coal Bearer.

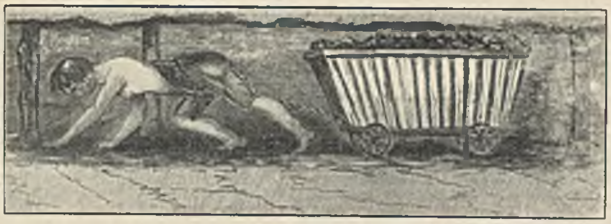


Fig. 3.—Girdle and Chain Haulage.

might be; he ensured comparative immunity from roof falls by driving narrow places, and, as a check upon his direction of advance, he observed from time to time the line of the endways cleat.

This pitman is assured of a minimum wage of fifteen shillings a week, with house and coals allowances in addition, but by dint of a laborious ten hours' shift below-ground can earn as much as four and sixpence if an adequate supply of corves is available. Corves are allotted to face workers by quota, however, and it is to bitter experience in this connection that may be attributed the pathetic spectacle that is presented by his being accompanied in the working place by a child of tender years. Old time conditions are best described by those who experienced them and in explanation of this child's presence in the pit, as of other customs to be noticed later, it is proposed to quote without comment typical extracts from evidence heard by a Royal Commission which enquired into methods practised at collieries at about the time we are considering. For example, Mr. Frederick Evans, Clerk and Accountant, says:—

" I have known instances of a father carrying his child of three years old on his back to the pit and keeping him in the stall all day for the purpose of having an additional tram allowed him. Children generally are brought to work for this purpose about five years old, however."

Coal won by the pitman must be removed from the working place to the main travelling way and is carried there, frequently by a girl, who for a twelve hours' shift is paid sixpence. This is what Nellie Jack, a coal bearer aged eleven years, has to say about it:—

" I have been working below three years on my father's account; he takes me down at two in the morning and I come up at two in the afternoon. I go to bed at six at night to be ready for work next morning. The part of the pit I bear in the seams are much on the edge. I have to bear my burden up four traps before I get to the main travelling road. My task is four to five trams. Each tram holds four and a quarter hundredweights and I fill five trams in twenty journeys. I am very glad when my task is wrought as it makes me so tired."

A brief description of this girl's work, abstracted from an eye-witness' notes, will serve to illustrate her evidence. After descending the pit she takes her creel, a basket formed to the back and not unlike a cockle shell flattened toward the neck, and proceeds to the working face. Here she lays down her basket into which the coal is rolled, and sometimes it is more than even a man can do to lift the burden on her back without difficulty. Next the tugs, or straps, are placed

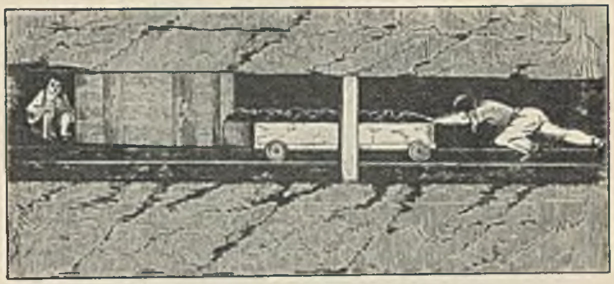


Fig. 4.—A Ventilating Door and Trapper.

around her forehead and her body bent into semicircular form in order to stiffen the arch. Lumps of coal are placed next on the neck and, after hanging her lamp to the head-straps, she commences her journey to the main travelling way. She has to traverse several roads, each about four feet in height, and ascend four ladders, each eighteen feet tall, before casting her load, of from one to one-and-a-quarter hundredweights, into the tram. This one journey is designated a rake. It is not easy to suggest an analogy to this girl's task of bearing coals on her back in the stooping posture described, but it is interesting to note that the heights ascended and the distance along the several roads added together exceed the height of St. Paul's Cathedral.

Loaded trams are propelled to the pit bottom by putters, each of whom receives one shilling for a twelve to fourteen hours' day. Mr. Tranter, Under Manager, describes the work in these terms:—

" When a child has to drag a carriage loaded with coals through a passage sometimes not more than twenty-eight inches in height some ingenuity is required to get his body and the carriage through this narrow space. The boys crawl on their hands and knees but an expedient has been adopted with a view to facilitating this labour. A girdle is put round the naked waist to which a chain from the carriage is hooked and passed between the legs: the boys crawl on their hands and knees drawing the carriage after them. This is called drawing by the girdle and chain. In some parts of this district girls are quite as commonly employed in dragging coals in this manner as boys."

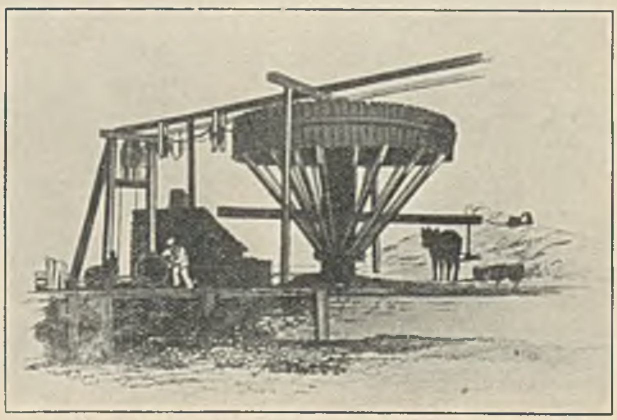


Fig. 5.—A Horse-driven Winding Gin.

Fig. 6.—Men Lowering Practice: Old Style.

A Commissioner adds:—

"One of the most distressing sights ever I have seen is that of young females, dressed like boys in trousers, crawling on all fours with belts round their waists and chains passing between their legs, at pits near Holmfirth, and New Mills."

Where the seams are thicker, notably on the West Cumberland coast, ponies are employed for this service, the coal being hauled outbye in corves set in pairs upon a tram or bogey. Difficulty arises where the steeper gradients are encountered, however, hence Mr. J. C. Symon's evidence that:—

"To prevent the baskets from rolling off the bogies and falling on the heels of the horses it is customary for the driver to place himself as a post between the foremost basket and the buttock of the horse. He places his left shoulder against the horse, his right foot against the rail of the tram, and his right hand on the top of the basket, the left leg either hanging free or being supported by the trace. The work is tiresome and dangerous, and though the position is not in itself, I think, injurious, the custom strikes one as a barbarous preference of the human body for a mere mechanical device."

En route to the shaft bottom ventilating doors have to be negotiated. These doors are tended by trappers who each are paid sixpence for a fourteen hours' day, and what follows is typical of evidence given by these youthful workers:—

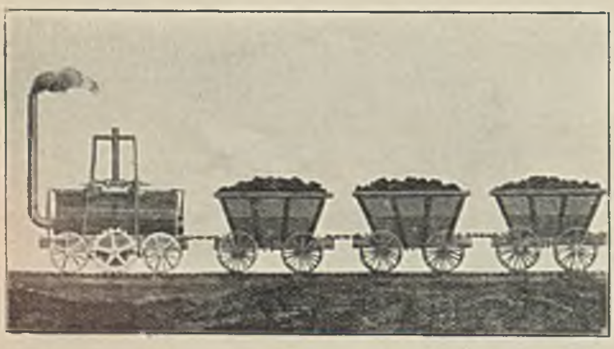


Fig. 7.—A Mineral Train hauled by the Blenkinsop Locomotive.

John Saville, seven years old, Collier's Boy at Soap Pit, Sheffield: "I stand and open and shut the door. I am generally in the dark and sit me down against the door. I stop twelve hours in the pit; I never see daylight only on Sundays. I fell asleep one day and a corf ran over my leg and made it smart so I wont fall asleep again."

Sarah Gooder, aged eight years: "I am a trapper at the Gawber Pit. I have to trap without a light and I am scared. I go at four and sometimes half-past three in the morning and come out at five and half-past in the afternoon. Sometimes I sing when I have a light, but not in the dark. I am very sleepy when I go sometimes in the morning."

One of the Sub-Commissioners: "I visited the house of the parents of a little boy whom I saw keeping a door down Flatworth Pit on the 30th May. It was about seven o'clock on a Sunday evening and the boy, Thomas Roker, was in bed asleep. His mother said he was aged about six years and seven months and that he had been down the pit several months. The boy was at school at three years old as his father wished to make him a better scholar before he went down. She always puts him to bed early because he must get up every morning at three o'clock, and he often rubs his eyes when he is woke and says he has only just gone to sleep. He gets up at three a.m. and goes down the pit at four o'clock. He gets his dinner directly he comes home about half-past four and then he washes himself and goes to bed between six and seven, so that he will never be more than two hours from the pit for eating, washing and playing. When his son gets a little more hardened to the pit his father means to send him to night school and stop an hour off his sleep. Thomas generally goes down the pit in a corf with a good few boys in it and sometimes he comes up on his father's knee. The pit does not hurt him but it makes him a little whiter and perhaps thinner. He was a very fat boy when he was three years old though."

The corves next are hooked to the winding rope by the onsetter and are raised to the surface, frequently by means of a horse-driven winding-gin, to be detached there by a banksman who also chalks down at intervals a record of output from the pit. Here also the coal is roughly sorted by women "whalers" whose day's pay varies from sixpence to ninepence, according to age.

Some of the coal is delivered ultimately at the colliery cottages, to be used there for firing purposes and so indirectly provides the bodily sustenance necessary to the renewal of the energy required for so arduous labour. How deplorable it is that the pitman should devote so little of his leisure time to healthful exercise of mind and body, and so much of it to habits of ostentatious luxury and extravagance. W. Thomas, Esq., of Denton Hall, is grieved at this, and, in response to a questionnaire by Sir John Swinburne, writes:—

"To excessive wages may be attributed many of the vices which attach to the character of the pitman. His wages give him more than sufficient to provide the necessities of life and it is lack of this necessity of prudence which leads to his surplus earnings being dissipated in riot and intemperance."

However, we must accompany him now upon his return to the colliery and as we step into the corf beside him must trust that greater care than usual has been exercised by the official responsible for shaft and rope examination. It will be as well not to have in mind the following typical evidence:—

"An accident occurred here in January whereby six men lost their lives entirely by negligence. They hooked the corf in which they were going to descend to a chain which had just received a violent concussion which cracked it. When they were being lowered into the pit the chain gave way and they were all killed. Another accident happened in February by which four men were killed. They were charter-masters and it was their business to examine the rope; this they neglected to do, so it gave way and they fell to the bottom. Two men and a boy were killed last month as well when the hook gave way. There is very great carelessness and those whose duty it is to examine things nearly always neglect to do so."

We return now to the working place and having seen the pitman once again take up his pick our first tour is ended. Altogether it is an experience that is best forgotten and as a sight of the river and the shipping may be helpful to that end we will ride down to the staithes on the iron rail way.

It is rumoured Mr. Stevenson intends to build a locomotive shortly; this engine was built to Mr. Blenkinsop's design and has been at work three years. Here is a description of it, taken from the *Tyne Mercury*:—

On Wednesday last a highly interesting experiment was made with a machine constructed by Messrs. Fenton, Murray & Wood, under the direction of Mr. John Blenkinsop, the patentee, for the purpose of substituting the agency of steam for the use of horses in the conveyance of coal on the iron rail way from the mines. This machine is in fact a steam engine of four horses power which, with the assistance of cranks turning a cogwheel and iron cogs placed at one side of the rails, is capable of moving when lightly loaded at a speed of eight miles an hour. At four o'clock in the afternoon the machine ran from the coal staith to the top of the moor where six and afterwards eight wagons of coals, each weighing three-and-a-half tons, were hooked to the back part. With this immense weight to which, as it approached the town, were superadded about fifty of the spectators mounted upon the wagons, it set off on its return to the coal staithes and performed the journey, a distance of about a mile-and-a-half, principally on the dead level, in twenty-three minutes, without the slightest accident. This invention is applicable to all rail roads."

THE SECOND TOUR: A.D. 1928.

Suppose now for our second tour we are met at the face at a colliery where modern methods are employed. Upon this occasion the journey is to be an extensive one for, whereas on the earlier tour we saw coal used indirectly to renew in the pitman the bodily energy expended by him upon his daily task, it will be seen that these now are conveyed to a distant power station for conversion there into the electrical energy which, upon delivery at the Colliery, is employed to actuate the various mining appliances installed on the premises.

We shall see great changes at the face; indeed if our visit is to a Northern Colliery we may find the face flood-lighted by electric lamps using alternating current, and at the least we each can be provided with an electric safety lamp designed to be effective not only as an illuminating device but as a detector of the presence of noxious gas as well.

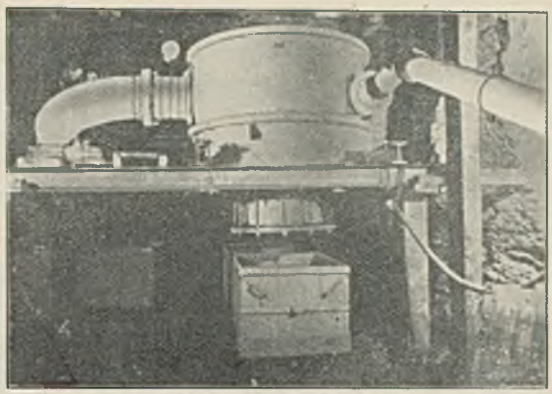


Fig. 8.—Pneumatic Conveyor Equipment: View at Loading Point.

The picks now are mechanically actuated, and as probably these will have been subjected to heat treatment in an electric furnace so contrived that uniform hardness and tempering automatically are ensured, bord and end cleat restrictions are less formidable than once they were. It follows that working places now can be arranged to best geographical advantage and that long-wall working is increasingly popular. One advantage of this arrangement is obvious; with the face length, average thickness of seam and cutting depth dimensions known and fixed, the daily yield of coal can be forecast by the management with reasonable accuracy.

The length of a long-wall face is not an arbitrarily fixed dimension: it is governed by several factors, one of which is that it shall not be longer than renders it practicable to shoot down and remove the whole of the machine-cut coal before it is assailed and crushed by the travelling weight of the strata, but a typical example is that of the Eccles Pit of the Backworth Coal Company, where four such faces, each 100 yards long, are set in line. Four face conveyors are installed, arranged to operate in pairs, so that the coal may be fed by gate-end loaders to two main conveying belts. These latter move at a speed of approximately one-and-a-quarter miles per hour and converge upon a central loading point located about four hundred yards out-bye from the working face.

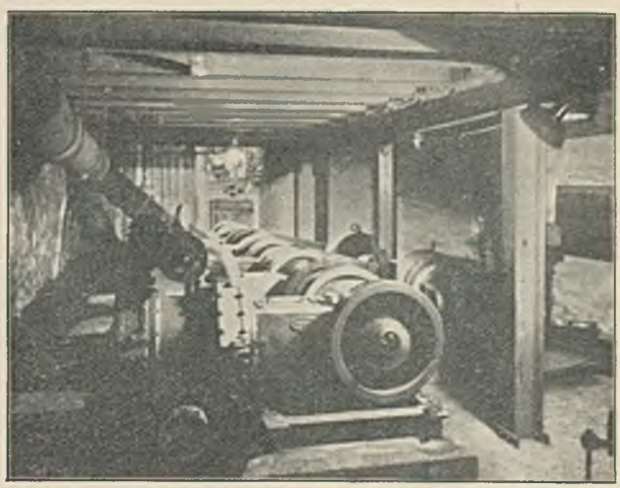


Fig. 9.—Pneumatic Conveyor Equipment: Underground Suction Plant.

Fig. 10.—*A Modern Power Station Lay-out.*

No longer is the pitman working upon his own account but as one of a gang organised to carry into effect a systematised machine mining scheme. Three shifts of men are employed, the first to cut and shoot down the coal, the second to remove the coal by casting it into the face conveyors already mentioned, and the third to dismantle, move forward and reassemble the face machinery in readiness for a coal cutting shift to continue the sequence of operations.

An alternative arrangement is being worked successfully at the Bowburn and Tursdale Pits owned by Dorman, Long & Company, Ltd., where coal is conveyed pneumatically from the face to the central loading point by means of suction pipes about seven inches diameter. The system is designed primarily for handling coking coal, and is particularly suited to thin seam working since the suction apparatus can be housed at some distance from the face and canch work costs almost entirely eliminated, but so satisfactory are the results already obtained that thicker seams now are being similarly equipped.

From the loading point the coals are drawn to the shaft bottom by main and tail or endless rope haulage, as the case may be. In this connection it is of interest to record that whereas until recently the electrical rating of haulage machinery has been determined almost invariably by conditions of maximum natural gradient in the pit, there now is greater readiness than formerly to take such steps as are practicable to "correct" abnormal gradients, so enabling the plant to be designed upon an economical root-mean-square basis.

Now that the tubs need be taken no further inbye than to the central loading point a practical proposition is to employ units of greater carrying capacity than hitherto has been customary. This is the modern tendency and tubs designed to carry twenty-five and, in one instance, forty hundredweights, of coal, are projected in the North of England.

It has been customary for some time to raise the coals to bank in cages designed to accommodate several tubs together and multiple deck equipment is commonplace. When we visit the winder house, however, we shall see that economies are practicable if the decking operation is accelerated; and, where an existing installation must be utilised, the desired result can be achieved by suitably altering the heapstead and shaft bottom lay-out to permit of the tubs on the several decks of the cage being handled simultaneously. If the shaft is new its diameter will be adequate and the plan dimensions of the cages such that the tubs which are to be raised together can be carried on a single deck.

Modern mining methods and the larger outputs resulting therefrom, necessitate high winding speeds and increasingly rapid rates of acceleration of the loaded cages. Rule of thumb methods, therefore, no longer will serve when winding ropes are to be chosen, for not only must account be taken of the strains that are due to statical and dynamical loading and to bending, but of the effect of kinetic shocks incidental to winding service as well.

The loaded tubs are raised to bank by an electrically-driven winding engine, the winding drum profile being designed suitably to compensate the heavy torques corresponding to acceleration and retardation of the masses involved, so ensuring an economical and safe winding cycle. Skilfully contrived automatic safety tripping and braking devices are fitted and so nearly is the possibility of accident eliminated that the older fashioned lay-out, intended to ensure to the engine-man an uninterrupted line of sight to the banking-out level, now is definitely discouraged.

The coal next is passed to the screening plant, the larger sizes being fed to the inspection belts to be hand picked. In this connection it is worthy of mention that careful investigation recently has been undertaken with a view to the adoption of more satisfactory lighting arrangements at these belts.

Coals varying in size from three-and-a-half to one inch probably will be fed to spiral screens, whilst that which is undersize for one inch mesh will be cleaned on tables of the pneumatic separator type. At these latter a certain amount of finely divided coal, undersize for thirty mesh and aspirated during the cleaning process, must be collected by means of exhauster and filtering apparatus provided for the purpose, and though this air-borne coal can be separated into coarse and finer grades and the heavier particles, amounting to about fifty per cent. of the whole, remixed with the cleaned product, it has been found that similarly to remix the very finely divided residue is impracticable. Interesting and successful experiments have been made recently by the Power Company in the transport and unloading of this coal "dust."

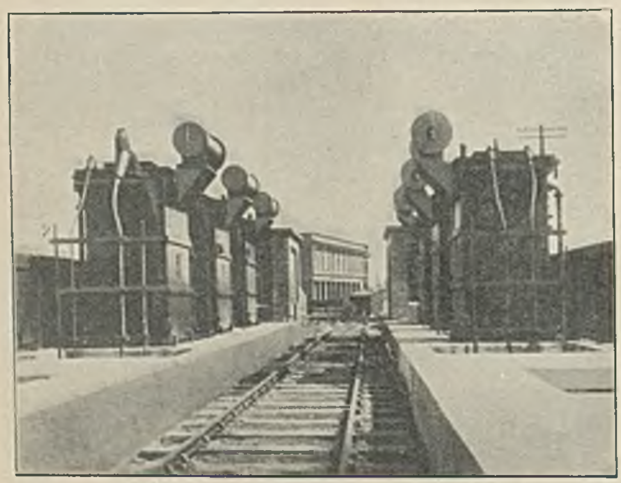


Fig. 11.—11,500/66,000 *volt Step-up Transformers at Dunston Power Station.*

Fig. 12.—66,000 *volt Transmission Line: River Tyne Crossing.*

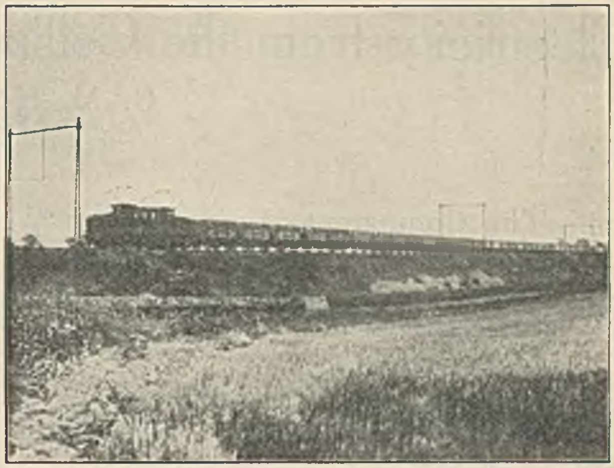


Fig. 13.—*A Mineral Train hauled by an Electric Locomotive.*

Coals of various sizes next are conveyed by rail from the colliery to the Power Company's generating stations, to be used there as boiler fuel in one form or another, and as more than half-a-million tons are required annually for this purpose, coal purchase arrangements must be systematic and thorough. Power supply charges to colliery consumers naturally are related to the purchase prices of the coals used in generating those supplies and an important factor in this connection is that adequate provision, neither more nor less, must be made against the risk of interrupted coal supplies due to strikes or other emergency. Incidentally, if the coals used in the course of a year at the several main stations of the Newcastle-upon-Tyne Electric Supply Company were to be loaded into standard railway trucks, these together would make up a train approximately two hundred miles in length.

Elevator and conveyor apparatus deliver the coal to storage bunkers from which it is fed to chain grate stokers or to powdered fuel burners, and so to the combustion chambers of water tube boilers of modern design each with an hourly evaporative capacity of seventy-five thousand pounds of steam, from and at two hundred and twelve degrees Fahrenheit. At the stations mentioned coal is consumed throughout the year at the rate of one ton per minute, and the average weight of steam generated each hour therefore may be taken to be approximately four hundred tons. The steam temperature is seven hundred and fifty degrees Fahrenheit, and it is interesting to observe that were this temperature to be raised by little more than a further one hundred degrees the ranges and other pipework would become visibly red hot.

The steam next is fed to the turbines of turbo-alternator equipment, each unit in this case with a capacity of twenty-five thousand kilowatts. These sets each are approximately sixty-five feet in length and the weight of the rotating members, revolving at two thousand four hundred revolutions per minute, is about forty-five tons.

The steam is exhausted into surface type condensers of large capacity and, when it is borne in mind that generating equipment of an aggregate electrical rating of four hundred and fifty thousand kilowatts is installed, it will be realised that very considerable quantities of cooling water are required. About one hundred and twenty-five million tons of water are raised to the surface annually from colliery workings in Northumberland and Durham, by means of electrically-driven pumps connected to the Newcastle-upon-Tyne Electric Supply Company's system. This is a tremendous quantity of water, but it is less than one-third of the volume used by the Company for condensing purposes.

Electrical energy is generated at eleven thousand five hundred volts and, by means of out-door pattern step-up trnsforming apparatus, is fed to the three-phase overhead distributing network at an electrical pressure of sixty-six thousand volts. This network already is more than two thousand square miles in extent and as collieries which are dependent upon the supply for essential services in some instances are located so far distant as forty-eight miles from the nearest generating station, carefully planned and supervised methods of system control are essential.

At outdoor substations, located in the colliery districts, the main transmission-line voltage is stepped down, usually to twenty thousand volts, and a supply afforded at that pressure to service apparatus housed upon the colliery premises. Here the pressure is reduced again, probably to two thousand seven hundred and fifty volts and, by means of switches, shaft feeder and inbye cables, the current then is conveyed to the primary windings of a step-down transformer housed belowground and in reasonably close proximity to the working face. At this point a four hundred and forty volts supply is made available for working purposes and is transmitted, by gate-end switch and trailing cable, to the coal-cutter motor which actuates the mechanically-driven picks from which, it will be recalled, this second tour is presumed to have commenced.

Now it is stupid to imagine that coal costs always can be reduced by the simple expedient of installing more machinery at the face or that a knowledge of the power problem at collieries is a valid excuse for interference with the mining engineer's legitimate business of coal winning. It is pardonable to claim, however, that the two distinct advances to which reference has been made in these notes—the wider application of electrical energy to mining processes upon the one hand, and a general betterment of underground working conditions upon the other—are due, at least in part, to the activities and interest of the electrical engineer.

Electricity from the Colliery Manager's Point of View.

G. M. HARVEY, M.Sc.

(*Continued from page* 91).

4.—The Competent Mining Electrical Engineer.

THOUGH the growth and complexity of electrical equipment in and about mines is universally conceded, it has not yet come to be generally acknowledged that the competent colliery electrician of to-day must differ very greatly from his prototype of the early haphazard days who was often little more than a wireman. As a good wireman he could connect up a machine; he could joint a cable after the crude fashion of those days; he could make minor repairs on straightforward types of D.C. and A.C. machines; and perhaps apply simple tests for insulation.

Modern developments may tend to simplify his work in some directions, but the great difference between the mining electrician of those days and the mining electrical engineer of to-day is that the former was a practical workman, relying wholly upon the result of experience and leaving technical considerations entirely to the consulting engineer or to the manufacturer: while the latter must combine practical experience with considerable technical knowledge. He must now be something more than a workman. He must be a technical engineer.

It is not suggested that technical qualifications should outweigh practical training. Without experience in handling apparatus under mining conditions, theoretical knowledge is little more than useless. On the other hand, experience is always of the greatest value though that by itself cannot qualify the man to cope with new developments and practical contingencies or emergencies; he must also have sufficient theoretical knowledge to understand the working principles of electrical plant and circuits.

Collieries to-day depend for continuity of production upon the services of a highly-trained electrical engineer; they are compelled to rely upon their permanent staff engineers, who are on the spot when any contingency arises. Delay in diagnosing the cause of a breakdown, and in planning and carrying out a repair, inevitably means loss—often very great loss.

Whilst primary responsibility must continue undivided and be individual to the colliery manager, he must perforce delegate the control and executive duties in some of the technical services to trusted employees expert in their respective subjects. Though a candidate for the post of Chief Electrician may possess sheaves of diplomas and certificates, but is without experience, he is worth nothing. On the other hand, a man with twenty years' experience would be valuable but he is not necessarily competent to take charge of a modern and rapidly developing mining electrical system. An experienced man must further bring conclusive proof of his technical knowledge. How is the colliery manager to weigh such evidence when selecting his staff?

The General Regulations for the Use of Electricity in Mines define the three classes of employees who must be appointed for electrical duties in writing by the Colliery Manager. The first is the Electrician, whose duty it is to supervise the apparatus and who is responsible for its maintenance in a condition of safety. The second is the Assistant Electrician, to whom the Electrician may delegate this duty, while retaining his responsibility. The third is the Authorised Person, which term covers any person whose duty it is to handle electrical apparatus. Under the last category come all motor-attendants, coal-cutter and conveyor man, switchboard attendants and deputies or firemen. The Electrician must be over 21 years of age, but no age limit is fixed for the Assistant Electrician or for the Authorised Person. All three must, however, respectively be competent to carry out their specific duties.

It is with the object of establishing a standard of technical knowledge that the Association of Mining Electrical Engineers decided in 1911, to award Certificates of Competency to its Members on the results of an Annual Examination. Two classes of Certificates were formulated corresponding to the standards desirable for the Electrician and the Assistant Electrician. Later an Honours Certificate was instituted, of the standard required for the Mining Electrical Engineer capable of taking complete administrative charge of the largest installation.

These Examinations have proved of value to the colliery electrician desirous of having definite proof that he is technically competent. They give him a standard of attainment at which to aim. They also serve to guide him in selecting suitable classes in the local Technical School should a regular course of classes specifically for the Association's Examination not be available.

The Certificate is of assistance to the manager in his selection of men for the post of Electrician or Assistant Electrician. No certificate is awarded to a candidate who has not had three years' practical electrical experience at a colliery, so that the Certificate is direct proof that the applicant is a competent person both technically and practically. It is, indeed, coming to be recognised by colliery managers that the possession of the Association's Certificate as an important factor should be taken into account when selecting men for electrical duties.

The Report of H.M. Electrical Inspector of Mines for the year 1923 reads:—"The Association of Mining Electrical Engineers, a Technical Society, with a view to fulfilling one of the primary objects with which it was formed, viz., 'to promote the general advancement of Electrical Science in its applications to the Industry of Mining,' holds voluntary examinations and issues certificates to those of its members who satisfy their examiners."

"These examinations point the way to the prescription of a definite standard of technical knowledge, the attainment of which must be to the ultimate advantage of the industry and of the Electricians themselves."

Put concisely, the Competent Colliery Electrician of to-day is a technically trained electrical engineer and, as such, his qualifications should be closely defined by the establishment of a definite standard of technical knowledge and experience.

Proceedings of the Association of Mining Electrical Engineers.

WESTERN SUB-BRANCH.

Cable Lay-Out and Protection: with Special Reference to the Smaller Colliery Installations.

J. A. B. HORSLEY
(H.M. Electrical Inspector of Mines).

PART I.—OBJECTS OF THE PAPER AND DISCUSSION OF LEGAL REQUIREMENTS.

The subject of this paper suggested itself to the author during the course of some recent inspections in the western area of the South Wales coalfield.

In some instances the Regulations bearing upon the subject had not been met adequately while in others unnecessary expenditure had been incurred in attempting to fulfil legal requirements. It is the two-fold object of this paper, therefore, to explain what is necessary in order to comply with the Coal Mines Act and to suggest how that provision can be made to the best advantage of the mine owner.

Regulation 128, which deals with the provision of switchgear, has a direct bearing upon the question and indeed this Regulation governs the issue.

There is another Regulation, however, that has an indirect but, nevertheless, a most important bearing upon the provision of a sufficient number of control points in the cable system.

That Regulation is 131 (e), which requires that "should there be a fault in any circuit the part affected shall be made dead without delay and shall remain so until the fault has been remedied."

Apart from, and perhaps in addition to, legal requirements—which, it should be borne in mind, prescribe only the minimum necessities—the demands of sound engineering practice must not be forgotten.

The Electricity Regulations do not purport to be an Engineering Specification: in them certain principles alone are enunciated.

In the Official Memorandum an attempt is made to indicate, withal briefly, the application of those principles but it may be as well in this paper to summarise, in plain words, the scope and purpose of Regulations 128 and 131 (e), as the author understands them, before proceeding to discuss their practical application.

Scope and Purpose of Regulations 128 *and* 131 (e).

Regulation 128 is divided into five sections, each covering one branch of the subject of the protection and control of the electrical installation, while Regulation 131 (e) definitely enjoins the use, under certain conditions, of the controlling devices that are postulated by the former Regulation.

It will be convenient to quote the words of the Regulations and to summarise the scope and purpose of each paragraph separately by the method of numbered annotations.

Regulation 128 (a).—"Properly constructed switchgear for cutting off the supply of current to the mine (1) shall be provided at the surface of the mine (2), and during the time any cable is live a person authorised to operate the said switchgear shall be available within easy reach thereof (3)."

"Lightning arresters, properly adjusted and maintained, shall be provided where necessary to prevent danger (4)."

(1) A switch or a circuit breaker of adequate rupturing capacity for use in any emergency; isolating links or switch-fuses will not suffice.

(2) The location may be the power station, or the local transformer sub-station or switch room above ground—provided the switchgear is at all times readily accessible to the person authorised to use it in emergency; or it may be arranged for remote control.

Alternatively there may be switchgear at the top of the shaft, or at the mouth of the mine provided for such emergency use alone.

(3) The authorised person or persons must be appointed in writing by the manager of the mine for this specific duty (see definition of "authorised persons" in Reg. 118) and he (or they) must be adequately instructed in the use of the switchgear. It is not necessary to select an electrician for this duty, but it is preferable, where possible, to do so.

(4) Lightning arresters are only necessary where the cables below ground are fed directly from an overhead line that is liable to inductive or static rises of voltage due to atmospheric disturbance.

The interposition of a transformer between the line and the cable is an effective lightning arrester if the neutral point of the secondary winding be earthed.

Spark-gap arresters with, or without, aerial choke coils of low impedance are of little value and may even aggravate pressure surges by initiating an oscillating discharge.

It is preferable to carry the shaft or mine cable direct to the power station, or transformer house, and to introduce a length of armoured cable between any incoming or outgoing overhead lines and the controlling switchgear therein. The cable serves as a condenser to absorb high-frequency pressure surges.

Regulation 128 (b).—"Efficient means (1), suitably placed (2), shall be provided for cutting off all pressure (3) from every part of a system (4), as may be necessary to prevent danger (5)."

(1) A switch (or a circuit-breaker if preferred), of adequate rupturing capacity; isolating links or switch-fuses will not suffice.

(2) Readily accessible to authorised persons, conveniently situated for the purpose for which it is intended to be used and introduced at that point in the circuit where it will be effective.

(3) The use of the switch must cut off all pressure from the apparatus or circuit controlled; it is not sufficient to interrupt the current if any part of the circuit, beyond the switch, is left at a maintained potential difference with earth.

A 3-pole switch for a 3-phase system; a 2-pole switch for a 2-wire insulated system; a single pole switch (in the live conductor) for an earthed concentric system.

Single-pole switches will not suffice for 2-wire lighting circuits, where both poles are insulated.

Single pole switches may be used for lighting circuits derived from one phase and the earthed neutral point of a 3-phase system, provided the single pole switch is inserted in the live conductor.

(4) One switch will not suffice for the whole of a complex system of considerable extent. There must be a sufficient number of switches to afford reasonable opportunities for their use and a reasonable assurance that they will be used to isolate parts of the system, when the need for such sectional isolation arises.

Generally, each branch circuit of any considerable length or importance should be controlled by a switch at its origin.

One main switch to control a distributing fuse board may suffice if the conditions are such that it will not be inconvenient to cut off the pressure from all the branch circuits for so long as may be necessary for the examination or renewal of the fuses that control one of the branch circuits.

It is preferable to interlock such a switch with the door giving access to the fuses to enforce the prior use of the switch.

(5) Each of the three preceding requirements is controlled, as well as qualified by this proviso.

The means must be efficient to prevent danger; suitably placed to prevent danger and in sufficient number to prevent danger.

Danger is defined (in Reg. 118) to include indirect danger from fire or explosion with an electrical installation, as well as direct personal injury from electric shock or burning.

Regulation 128 (c).—"Such efficient means (1) shall be provided in respect of each separate circuit (2) for cutting off all pressure automatically (3) from the circuit or part or parts of the circuit affected in the event of a fault (4) as may be necessary to prevent danger (5)."

(1) Implying efficient means suitably placed to effect the object of this Regulation.

(2) Here there is no ambiguity: unless omission will not introduce danger that inclusion would obviate then automatic electrical protection must be provided for each sub-circuit.

(3) This requirement differentiates this from the preceding section (b) of Regulation 128.

The means must operate automatically: it may be either a circuit-breaker, of adequate rupturing capacity with trip coils that will cause the breaker to open the circuit, or fuses, which must also be of adequate rupturing capacity and efficient for the purpose.

(4) This prescribes the purpose which the automatic cut-out is intended to fulfil. It is to isolate any part of the circuit upon the occurrence of a fault in that part.

A fault means primarily a failure of insulation, either between two or more live conductors or between any live conductor and earth.

A fault does not ordinarily mean an overload but a failure of insulation may follow if an overload is sustained. However, dangerous overloading whether of cables or of apparatus, is covered by the terms of Regulation 124 (a), which requires that all apparatus and conductors shall be, *inter alia*, "worked so as to prevent danger, so far as is reasonably practicable."

Except in the case of an earthed system, e.g., a 3-phase system with earthed neutral point, or a concentric system with one pole earthed, overload trip coils or fuses will not ensure isolation of the circuit if a fault i.e., a failure of insulation occurs on one phase or pole, unless there is an existing similar fault elsewhere upon another phase or pole of the same system.

Complete protection is given by the addition of leakage protection to the ordinary overload protection.

(5) The protective automatic contrivance must be sufficiently sensitive and sufficiently rapid in action to isolate the circuit before the fault results in dangerous conditions.

The design and setting of overload trip coils or the grading of fuses should be appropriate to the circuit, i.e., the device should prevent any sustained current in excess of that which is safe for the cables or apparatus included in the protected circuit.

Regulation 128 (d).—"Every motor shall be controlled by switchgear for starting and stopping (1), so arranged as to cut off all pressure from the motor and from all apparatus in connection therewith (2), and so placed as to be easily worked by the person appointed to work the motor (3)."

(1) Ordinarily this means a separate main switch, or circuit-breaker. In the case of a squirrel cage induction motor, which is arranged to be started by connecting the motor directly to the line, one circuit-breaker suffices for this Regulation as well as for the purposes of Regulation 128 (c) as far as the motor is concerned.

A squirrel cage motor, however, may be started in two stages, e.g., by connecting the stator windings to the line, first in star and then in delta, or mesh connection or, by connecting the terminals of the stator winding, in the first stage, to an intermediate tapping upon an auto-transformer before applying the full line voltage.

(2) In either of these two examples that have been given above one circuit-breaker will suffice, provided it is designed with an off position, in which the motor and the auto-transformer, if any, is completely isolated from the line.

It may be necessary to have local means for isolating the main switch in order to comply with Regulation 128 (b), so as to facilitate periodical examination of the switch. For this purpose there may be an isolating switch, i.e., a switch that is not designed to break load current, between the main switch and the line, or the main switch may be of the self-isolating draw-out type.

(3) The main switch must be readily accessible to the motor attendant. It need not be immediately adjacent to the motor: if there is also a starting switch or a controller, the main switch for the purpose of this Regulation may be that at the origin of the branch circuit in a distributing switch house near by, provided that it can be easily worked by the motor attendant. This proviso could be met in such a case by the use of a contactor switch, with push button control from the motor room.

Some starters and controllers include a main switch or circuit-breaker in the same housing or enclosure. Subject to the provision of local means for isolating the whole apparatus, where such isolation is necessary for the avoidance of danger, or to facilitate routine examination, no other main switch is necessary to comply with this Regulation.

This does not exclude the need for automatic protection, which is covered by Regulation 128 (c) so that, unless such automatic means are included in the starter or controller it may be necessary to add a separate main circuit-breaker, or a separate main switch and fuse.

Regulation 128 (e).—"If a concentric system is used (1) no switch, fuse, or circuit-breaker shall be placed in the outer conductor, or in any conductor connected thereto (2), except that, if required, a reversing switch (3) may be inserted in the outer conductor at the place where the current is being used. Nevertheless, switches, fuses, or circuit-breakers may be used to break the connection with the generators or transformers supplying the electricity (4); provided that the connection of the outer conductor with the earthing system shall not thereby be broken (5)."

(1) For the purpose of the Mines Regulations, a concentric system is defined in Regulation 118 to mean an electrical system connected to a common source comprising two conductors, one of which, called the inner conductor, is insulated and is more or less completely surrounded by the other, which is called the outer conductor. In colliery practice the application is limited to direct current, and the outer conductor is connected to the negative pole of the generator. Regulation 124 (c) (iii) requires that this outer conductor shall be earthed by connection to an earthing system at the surface of the mine.

Regulation 129 (a) permits the use of concentric cables with a bare outer conductor and Regulation 129 (c) exempts such cables from the requirement, applicable to other systems that they shall be protected by an iron or steel armouring. Such an unarmoured cable, however, would have to be installed in such a way as to comply with Regulation 129 (b), which requires efficient protection from mechanical damage, and also with Regulation 129 (d), which prescribes attachment to insulators, by non-conducting and readily breakable material.

In practice, concentric cables for colliery use always have an external and usually bare armouring of steel wires.

(2) This necessary prohibition adds to the difficulty of the designer in providing adequate rupturing capacity in switch, fuse and circuit-breaker because, other things being equal, the ability of such a device to open a circuit successfully under load depends upon the number of simultaneous breaks in series.

(3) If a reversing switch is used, e.g., to change the polarity of a direct current motor armature in order to reverse its rotation, it follows that the motor windings must be insulated from the earthed framework entirely. This is the usual practice; both ends of all windings are brought to insulated terminals.

(4) This permits the use of a double pole circuit-breaker between generator and switchboard bus-bars, subject to the next requirement, and so facilitates testing the insulation of the generator.

(5) This requirement is quite simply met by earthing the negative bus-bar to which the outgoing circuits are connected.

Regulation 131 (e).—"Should there be a fault in any circuit (1) the part affected shall be made dead without delay (2), and shall remain so until the fault has been remedied (3)."

(1) Here the term fault clearly means a failure of insulation, i.e., either a short circuit between poles, or phases, or a failure of insulation between a normally insulated pole, or phase, or earth.

(2) This means that any circuit, or part of a circuit in which a failure of insulation has occurred must be isolated immediately from the remainder of the system. For example, it is not permissible to continue to operate any part of a normally insulated 3-phase system in which one phase has gone to earth. This requirement, therefore, postulates means to detect such failure of insulation and means to isolate the faulty circuit, without delay.

(3) This merely completes the declaration by prohibiting the re-connection of a faulty circuit until the fault has been remedied: to enable this to be done the fault must first be located. Unless the cable network is sufficiently sub-divided by switchgear, delay is bound to occur in isolating a faulty section and, subsequently, in locating the fault.

PART II.—PRACTICAL APPLICATION OF THE REGULATIONS.

The practical applications of Regulation 128 can be shown most readily by diagrams such as those following.

It is not always realised that where there are two, or more, shaft feeders in parallel, it is always desirable and is sometimes necessary to provide switchgear for each of the cables at the pit bottom or delivery end.

Such duplicate, or multiple, feeders may be of equal or of unequal current carrying capacity.

If the cables are of equal load capacity, i.e., if they are of the same type and have conductors of the same sectional area then automatic protection at both ends is not necessary. If, however, the load capacity is unequal then automatic protection is necessary at both ends of the cable which has the smaller load capacity. This will be obvious if we regard the smaller cable as an extension of the larger cable, or as a branch from it.

A diagram, Fig. 1, will make this clear.

Fig. 1 shows duplicate shaft feeder cables of unequal current carrying capacity.

A fault on the smaller cable at f (a) will be fed by both cables, and as the setting of the circuit-breaker at (b^1) may be in excess of the safe load for cable (A) it is necessary to have the circuit-breaker (a^2) to protect the smaller cable.

This figure shows cable (B) connected directly to the bus-bars at the pit bottom, viz., at (b^2).

If a fault occurs on cable (B) at f (b), as there is no switchgear at (b^2) it will be necessary to cut off all current from the mine before the fault can be isolated by disconnecting cable (B) at (b^2).

If a switch (or a circuit-breaker) is provided at (b^2) it will add to the convenience, for a switch at that point will enable cable (B) to be isolated without delay either in case of a fault at f (b), or for routine testing of the shaft feeder cables.

Sometimes one of two duplicate feeders is kept isolated as a spare cable, but that involves idle capital.

Duplicate feeders are provided either because one alone will not carry the whole load or because duplication is considered worth while to ensure continuity of supply.

Uninterrupted service can be made reasonably certain by the installation of duplicate feeders with automatic discriminating protective switchgear at both ends of each cable. By this is meant automatic switchgear that will isolate the cable upon which a fault occurs while leaving the sound cable to continue the service.

Discriminating feeder protection is now a commonplace application in 3-phase systems for public supply.

For small colliery installations, however, duplicate feeders with switchgear of the ordinary type at both ends suffices for practical requirements.

Fig. 2, which is a variant upon Fig. 1, shows two shaft cables of equal load capacity with a duplicate feed to a pump in a shaft inset.

In this case switchgear is shown at both ends of each shaft cable with the object of facilitating quick isolation of a faulty section of feeder, so as to maintain the supply to the pump through either feeder.

Isolating links are shown at (x) and at (y), but if continuity of supply to the pump is of vital importance, it would be worth while to add switches at these points.

In case of a fault on cable (A), e.g., at f (a), this can be cleared quickly by means of the switches at (a^1) and (a^2), thus continuing the supply to the pump and to the mine through cable (B).

If there is a fault on cable (B), e.g., at f (b^1), the use of the switches at (b^1) and (b^2) will enable the supply to be restored to the mine through cable (A) while the isolating links at (x) are withdrawn pending resumption of the supply to the pump through cable (A) and the sound section of cable (B) from the pit bottom.

Apart from the incidence of cable faults the arrangement shown saves time in the routine testing of the cables, indeed if there are switches at (x) and (y) the shaft cables can be isolated and tested without interrupting the supply to any part of the mine.

It is not necessary that each cable shall be capable of carrying the whole load continuously.

The whole load, or at any rate the more important part of the load, can be carried by one of two such cables, for a time, at the expense of increased drop of pressure and with some rise in temperature.

Upon medium pressure systems the drop in pressure is usually the determinant, while upon high pressure systems temperature will probably limit the load that can be carried normally.

Fig. 3 shows one incoming district feeder cable, two branch feeders, with successive tappings from one of them, e.g., for coal cutting machines or for putting haulers or for conveyors in a district that is being developed. This is a special case, where all the cables in the district are assumed to be of equal current carrying capacity and where all serve the same purpose. Here the sub-circuits are not permanent for when (a^4), the sub-circuit cable furthest inbye is laid, that at (a^1), furthest outbye, will no longer be required and will be removed.

The branch feeder is protected at its origin, by the circuit-breaker, or switch and fuses at (a); the question is whether similar means of control are required at the origin of each sub-circuit. Obviously some means for disconnecting each sub-circuit cable from the branch feeder will be a great convenience, amounting almost to a practical necessity, even if it is not a legal requirement to provide switchgear at the points (a^1), (a^2), (a^3) and (a^4).

Proceeding upon the assumption (i) that none of the sub-branches are of great length and (ii) that there will be no serious inconvenience in cutting off the pressure

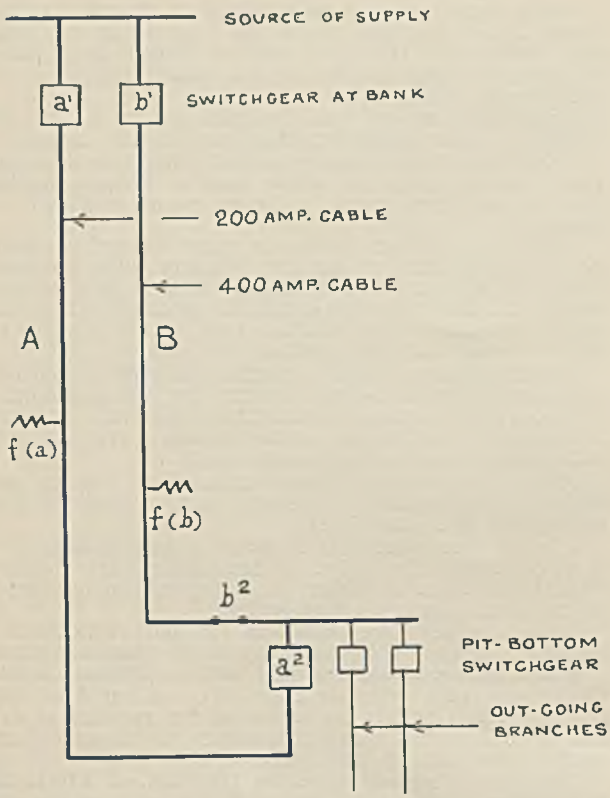


Fig. 1.—Duplicate Shaft Feeder Cables of Unequal Current Capacity.

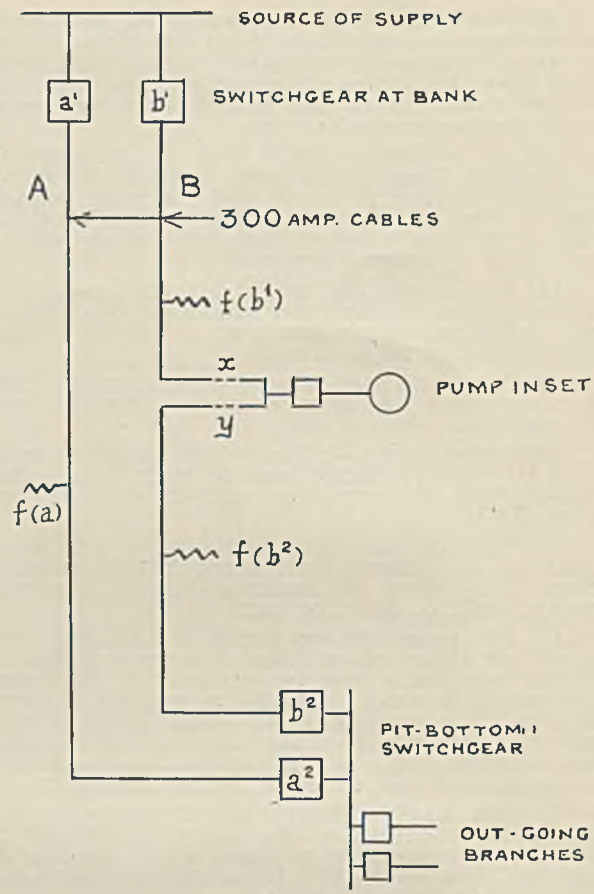


Fig. 2.—Duplicate Feed to Pump in Shaft Inset: Shaft Cables of Equal Current Capacity.

from the whole of them for a short time, in order to effect isolation of any sub-branch circuit, either because of a fault or for testing or replacement of any of the apparatus on one sub-branch, it may be said that switchgear to control each sub-branch is not necessary.

A word of caution is required, however, to point out that as the distance increases between (a) and the first sub-branch (a^1), it may be necessary, or at any rate advisable to add another control switch in the branch feeder at position (x), so that in case of any accident there shall be means within reasonable distance of the advancing coal face whereby all pressure can be cut off from the district.

Now as to the means, alternative to switchgear, that should be provided for disconnecting each sub-branch at its origin; obviously Tee joints in the cable, insulated and sealed with compound, as all such joints ought to be sealed, will not meet the needs of the case.

A link disconnecting box is the minimum requirement, but such a box of the ordinary type necessitates tedious removal of the sealing compound preparatory to removing the link box from (a^1) to (a^4).

Indeed it would be better, and probably cheaper, to leave the link box for future use as a testing point and to cut off and seal the branch circuit cable close to the box.

There is, however, a simple and satisfactory solution to be found in the use of standardised cable-end boxes assembled as components to form a disconnecting box, at each of the positions (a^1), (a^2), (a^3) and (a^4).

The principle of construction of such composite cable boxes will be explained in Part III.

Let us consider next the case where loads of diverse type and various denomination are fed successively, but not necessarily simultaneously, from a single feeder, such as a cable in a long "slant."

Fig. 4 illustrates such an installation.

In this lay-out the first motor, inbye, at (a) is fed by looping the feeder cable into the bus-bar chamber of the main switch, preferably through isolating links so as to facilitate piecemeal testing.

At (b), as the length of the branch to the next motor is not inconsiderable, a Tee box with disconnecting links is shown. This branch cable is presumed to be equal in current carrying capacity to the cable in the slant. At (c) there are two branch circuits of unequal current carrying capacity and each less than the main feeder, so at this point there are two circuit-breakers. One of these (d) serves as the main switch for the local motor while the other (c) controls the section of smaller cable that continues down the slant.

It will be seen that the cable system is sectionalised so that each part can be isolated with a minimum of disturbance or delay for routine testing, or to facilitate the localisation of a fault.

If the branch from (b) is a long one supplying one or more motors, it will be worth while to introduce a switch at (x), looping the slant cable into the switch, as suggested at (a).

These four Figs. cover most of the variants likely to be met with in small colliery installations.

PART III.—

(*a*) COMPOSITE DISCONNECTING CABLE BOXES; (*b*) CIRCUIT BREAKERS AND FUSIBLE CUT-OUTS.

(*a*) *Composite Disconnecting Cable Boxes.*

This term has been coined to signify an assembly of cable-end boxes of special design arranged to form a convenient disconnecting point in the cable system.

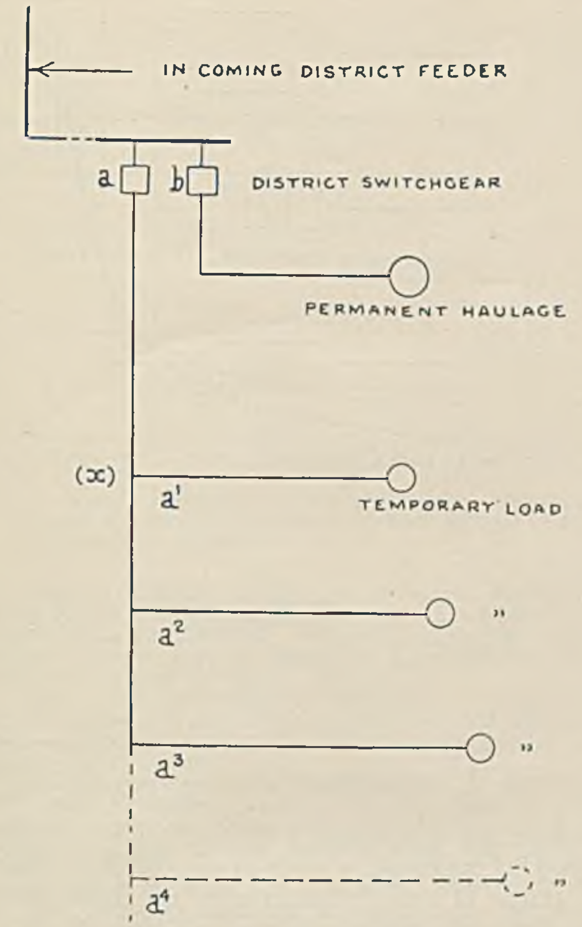


Fig. 3.—Branch Feeder with Temporary Tappings: all Cables of Equal Current Capacity.

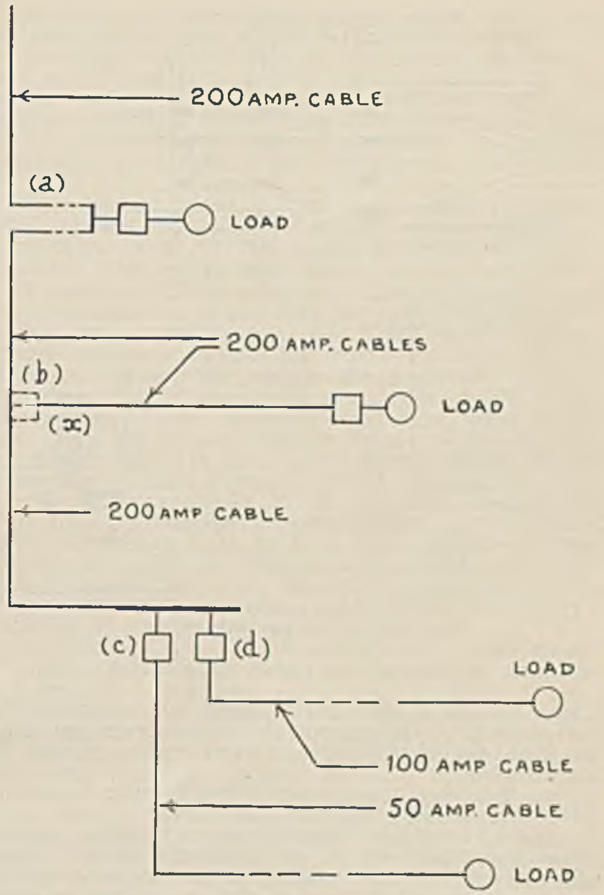


Fig. 4.—District Feeder with Tappings and Extensions of Reduced Current Capacity.

The principle of such a composite cable box can be seen readily from the diagram, Fig. 5.

The novelty which distinguishes this arrangement from an ordinary cable joint box, either with or without accessible disconnecting links, lies in the use of a detachable cable-end box for each branch cable. The cable insulation, i.e., the dielectric, is sealed in the usual way by the use of molten insulating compound in the dividing box but the sealing is done once and for all and the armouring of the cable is attached permanently to the box, for there is no need to disturb the cable end when local alterations have to be made in the cable system.

Moreover, the conductors could usually be soldered into the terminals, because the box can be attached to the cable before bringing it into the mine.

The adaptability of this arrangement is shown in Fig 6.

Fig. 6 shows at (a) one box terminating a length of cable at a gate-end switch; at (b) the substitution of a second box, in place of the switch, when it is desired to extend the cable, i.e., two similar boxes are joined to form a straight-through cable joint box.

At (c) three boxes are shown associated to form a three-way cable junction; while at (d) four boxes are shown making a four-way cable junction.

At some collieries the importance of sealing the cable dielectric is not realised, and even where it is practised near the pit bottom it is omitted as the coal face is approached. One reason that is often given for this omission inbye is that the cable is impermanent and that it will be extended or rearranged after a few weeks or maybe months.

If the method of dealing with the cable-ends, illustrated in Figs. 5 and 6 is adopted, there will be no motive for the omission of such an important precaution in preserving the insulation of cable from the insidious attack of moisture. Indeed there is no reason why each new length of cable should not have the cable box attached in the workshop, above ground, before it is taken into the mine.

(b) Circuit Breakers and Fusible Cut-outs.

For the broad purposes of this discussion, circuit breakers and fuses may be regarded as equivalent and alternative means for isolating a circuit automatically when the current is of such magnitude as to endanger, immediately, the cable or the apparatus in the circuit.

It is necessary, however, to understand in what respects these two alternative means differ essentially. The fuse in its simplest form comprises a short length of wire, in a convenient holder, between two terminals. When a current of sufficient magnitude flows through the wire for a sufficient length of time the fuse is melted and, in melting, opens the circuit. As this paper is written in the hope of interesting and informing some who lay no claim to electrical knowledge, it is necessary to emphasise the incidence of these two factors, current and time, in determining the operation of a fusible cut-out.

It is usual to speak of fuses in terms of current only, saying "we use 10 ampere fuses here and 100 ampere fuses there." There is often a misunderstanding at the very outset, however, involving the rating of the fuse.

A 10 ampere (or a 100 ampere) fuse may mean, in the mind of the speaker, one that will open the circuit when a current of 10 amperes (or 100 amperes) is sustained sufficiently long to melt the fuse, or it may mean

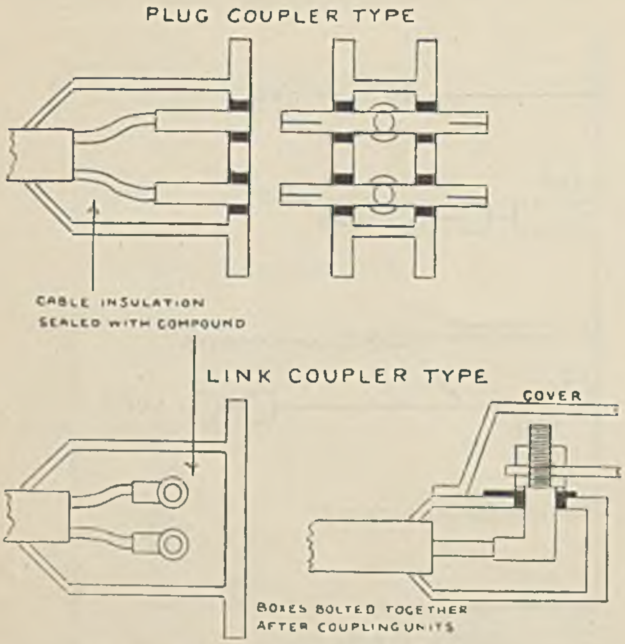


Fig. 5.—Diagram of Cable-end Coupling Box.

a fuse of such a size that a motor with a normal full load current of 10 amperes (or 100 amperes) can operate upon the circuit without unreasonably causing the fuse to blow.

In that case the sustained fusing current is probably thrice or twice the full load current.

There is another common misunderstanding that involves circuit breakers as well as fusible cut-outs. Some who are not electricians think that the inclusion of such a device in the circuit ensures that no current in excess of that for which the device is set to operate can flow. Certainly no current seriously in excess of that of the setting can be sustained without operating the device but momentarily the current that may flow is quite independent of the size of the fuse wire or the setting of the circuit breaker. To begin with there is the time factor, and Fig. 7 is introduced to illustrate the relation between time and current in the operation of a fusible cut-out.*

To continue, the current that may flow, before the device operates and opens the circuit, depends only upon the ability of the generator or transformer to supply current and upon the resistance (and reactance) of the circuit.

Actually, therefore, 100 or 1,000 or even 10,000 amperes may flow momentarily through a fusible cut-out, or through a circuit breaker, that is designed to operate if a current of, say, 10 amperes persists for, say, one minute.

Under such conditions the disruption may be very violent, therefore adequate rupturing capacity is required of the circuit-opening device.

It is not enough that the cut-out or the circuit breaker shall be capable of carrying the normal full load of the circuit; it is also necessary that it shall be capable of clearing, without danger, the most severe short-circuit that may occur in practice.

A circuit breaker differs from a fusible cut-out in the principle upon which it operates, as the determining factor is not heat but the electro-magnetic field due to the current flowing in the trip coils. It does not, therefore, possess as an inherent and inseparable characteristic a time lag, other than that due to the inertia of the parts. A time-lag, however, is so valuable a feature for many

*From the Paper by P. D. Morgan, B.Sc. (Eng.), Journal of the Inst. of Elec. Eng., Vol. 66, No. 381, September, 1928.

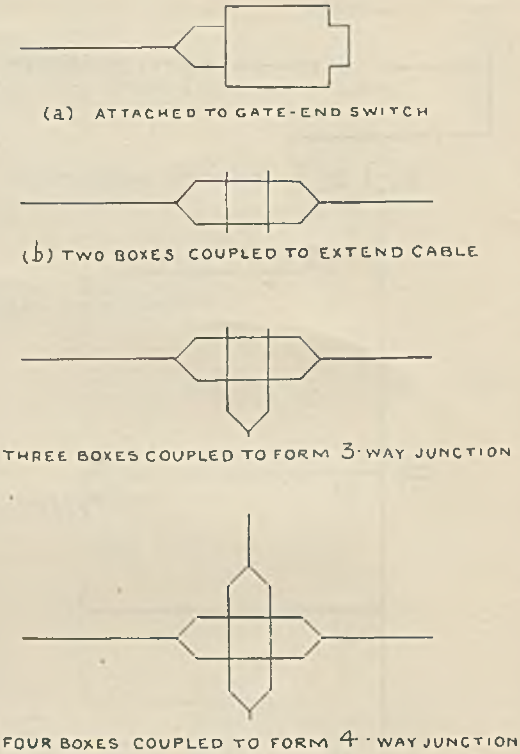


Fig. 6.—Assembly of Cable Coupling Boxes.

purposes that it is introduced deliberately either by shunting the trip coil with a fuse, or by adding a dash-pot to the tripping device.

Either of these devices gives to the circuit breaker an inverse time/current characteristic similar to that inherent in the fusible cut-out.

For particular purposes a circuit breaker can be given retardation that is definite and independent of the magnitude of the current, for example when it is desired to ensure that a main circuit breaker, between generator or transformer and bus-bars, shall not trip simultaneously with a circuit breaker protecting a branch circuit upon which a short-circuit has occurred.

Looking at the matter as a problem in automatic protection, it is probably better to use such a definite time lag upon certain circuit breakers rather than to attempt to make them selective by raising their overload setting or by increasing their retardation, where dash-pot time lags are used.

Let us consider now some of the differences in the practical application of fusible cut-outs and of circuit-breakers.

First there is the question of cost, but the author understands that to-day there is but little difference in the first cost of a circuit breaker and a well made switch and fuse, at any rate in certain sizes.

The circuit breaker is a more complicated piece of mechanism and therefore requires more skilled maintenance but, subject to that requirement, circuit breakers give perfectly reliable service.

If comparison is made between a circuit breaker and a fusible cut-out of the type in common use, there can be no question that the former is the instrument of greater precision, viewed as a safety valve.

The trip setting of a circuit breaker is constant and it is known and precise, while the retardation can be adjusted within wide limits to suit particular conditions.

In the case of a fusible cut-out of the common type, the rating can be adjusted within limits by selection of the fusible link, but it is influenced materially by the condition of the contacts and by small variations in the assembly which determine the development and loss of heat.

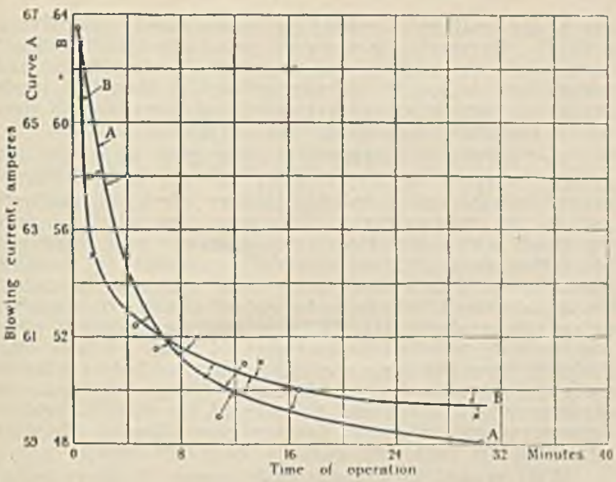


Fig. 7.—Time: Current of Fusible Cut-outs; 20 s.w.g. Tinned Copper in Porcelain Holder in Iron Case, Low-pressure types.

There is also the difficulty of preventing tampering with a fusible cut-out, i.e., the insertion of a fusible link of excessive rating, and the loss of time incurred in replacing a blown fuse as compared with re-setting the handle of a circuit breaker.

There is one other point of difference. A fusible cut-out can only give protection against overload currents while a circuit breaker can be designed to be tripped by leakage currents also.

Leakage protection, in a workable form, is comparatively new to colliery practice, but the value of this additional protection is now generally admitted and it is coming to be regarded as essential upon high voltage systems, especially where there is generating or transforming plant of large size. However, that is a subject that cannot be discussed at length here, and it is one that has been dealt with in a number of papers read before this Association in recent years.

Usually one finds circuit breakers for the protection of cables near the pit-bottom, and fusible cut-outs in-bye. It would appear to be more logical to reverse the application and to rely on fuses at the origin of the main cables and to use circuit breakers in-bye, where more frequent operation results in loss of time and greater inducement to tampering, because it is easy to lock the adjustment of the circuit breaker against unauthorised persons while leaving the handle free for re-closing the circuit.

Owing to the deficiencies and limitations of the ordinary type of fusible cut-out the author hopes that this suggestion to substitute fuses for circuit breakers will not be taken too simply.

There are, however, great possibilities yet in the fusible cut-out as a simple means of clearing a circuit under overload, even under very severe short-circuit conditions.

Fusible cut-outs are available which are capable of reasonably precise and close setting with large rupturing capacity, but these do not appear to have found their way into collieries as yet.

While improper replacement of blow fuses is the bugbear of the fusible cut-out, regarding it as a safety valve, it is not uncommon to find circuit breakers in an equivalent condition, and the author hopes that this part of the paper may be the means of directing attention to these automatic safeguards, so that the outlay incurred in providing them shall produce an adequate return in effective insurance against the consequences of defects in the machinery and cables which comprise the installation.

Discussion.

Mr. YATES opening the discussion, said thanks were due to Mr. Horsley, not only for his most useful and interesting paper, but because he had given special consideration to the needs of the West Wales Collieries.

From the point of view of all present, the importance of efficient cable lay-out was summed up in the sentence with which Mr. Horsley concluded Part I. of his paper—" Unless the cable network is sufficiently subdivided by switchgear, delay is bound to occur in isolating a faulty section, and subsequently, in locating the fault."

When reading through this paper, Mr. Yates said there appeared to him to be one or two difficulties which might arise in the practical application of the principles contained in this section of the Regulations.

Regulation 128 (c) calls for automatic protection of branch circuits and, whilst they all appreciated the need of this, the difficulty in certain cases was to obtain suitable switchgear. Assuming that a roadway cable of 0.4 sq. in. cross-section had to be tapped to serve a small pump, which only required a feeder of 0.05 sq. in. cross-section. A Tee joint-box had to be fitted in the main cable and a short branch taken to the isolating switch-fuse: the Tee box must be of special design to take the .4 cable through and the .05 from the Tee. The alternative would be to fit a standard Tee for 0.4 cable and use this larger cross-section to the switch, which would then have to be a much larger size than the job called for in order to accommodate the cable. What is needed for a job of this sort is a combination of joint-box and switch-fuse; Mr. Yates said he did not know of one on the market at present.

Regulation 131 (e) states that a faulty circuit should be made dead without delay and remain so until the fault has been remedied.

Distribution commences at the Power Station switchboard and the whole of the underground supply is fed as a branch circuit from that board. Should an earth fault occur upon this circuit, the switchboard attendant is required by this regulation to open the underground circuit and let it remain open until presumably, he is notified by the electrician that the fault is cleared. Suppose, for instance, that the faulty insulation is upon a controller at an inbye haulage, how is the electrician to trace and isolate the trouble? The haulage-driver will have opened his switch or circuit-breaker, as soon as his supply is cut off, and even "Megger" tests at the various isolating points would fail to locate the fault; but if the switchboard attendant re-closed his underground circuit-breaker upon the fault until such time as the electrician could get to his underground sub-stations, the fault could be easily located and isolated and a very expensive delay prevented.

Mr. S. T. RICHARDS said that the subject with which Mr. Horsley had dealt was one of vital importance to all colliery managers and electricians, as it concerned the control and consequently the prevention of dangerous currents. Mr. Horsley had dealt with his subject in a very thorough manner, yet in a form which could be understood by the layman. It was all the more interesting to this Branch of the Association inasmuch as some recent inspections in that area had suggested the subject to the lecturer.

In Part I. Mr. Horsley had given a very lucid explanation of the different sections of Regulations 128 and 131 (e), and they were indebted to him for his suggestions as to what is required for compliance with them, also for indicating what did not comply. Mr. Horsley said there were doubtless many cases where, owing to misinterpretation of such clauses, expensive apparatus had been installed; and, again, cases where necessary apparatus had been omitted altogether.

In dealing with switchgear, Mr. Horsley mentioned, and rightly so, that this should be of adequate rupturing capacity. It is very important that all switchgear used at collieries should be perfectly safe to rupture the short circuit currents at their respective locations. Mr. Richards thought this question of rupturing capacity of switchgear introduced a problem for the colliery electrician in coming to a decision as to what make of switch he could recommend being installed. If he required a switch of a certain rupturing capacity, and obtained particulars and tenders he found that each manufacturer stated that it had the required rupturing capacity. On comparing details, however, he would find that in no two cases were the "speeds of break" the same, nor the clearances between poles and earth, or poles or phases to each other. Each had a different head of oil, and there did not seem to be any degree of standardisation in the matter. Instead of adapting their sizes to rupturing capacity, they adapt the rupturing capacity to their sizes. Possibly some of the manufacturers might offer some explanation. It appeared to him that a good deal of present day switchgear had very frequently an actual rupturing capacity less than its rated values.

Referring to lightning arresters, Mr. Horsley had suggested that these were only necessary where the cables below-ground were fed directly from an overhead line that is liable to inductive or static rises of voltage due to atmospheric disturbances, also to introduce a length of armoured cable between any incoming or outgoing overhead lines and the controlling switchgear, this cable serving as a condenser. Mr. Richards asked whether the underground cable itself would not be of sufficient capacity to absorb these surges without damage.

Referring to Reg. 128 (c), clause 4, the lecturer in his comments stated that complete protection is given by the addition of leakage protection to the ordinary overload protection, and Mr. Richards agreed with him. He said he had had occasion recently to consider the question of leakage protection on D.C. circuits, and he favoured the Couse Rosebourne system. On going into the question of costs, he found that for installation in conjunction with a 600 amps., D.P., 500 v., circuit breaker the price for this gear was £107. This was for switchboard mounting in the power house. The original price of the circuit breaker was £26. Again, for use in conjunction with an oil immersed underground D.C. distribution board for the main incoming switch, the cost was £130. This astonished him, and he took the matter up with the firm holding the Patent rights, but found no better terms could be obtained. The cost of installing this system throughout at a small colliery would be very heavy. He would like to know whether any other engineers had similar cases. In the case referred to, selective operation was required. He asked whether Mr. Horsley could give some particulars as to probable costs of some of the installations he knew which had adopted similar gears.

He was pleased to note that in Part 2, Mr. Horsley mentioned that automatic protection at both ends is unnecessary with cables of equal load capacity. He knew cases where the idea prevailed that the cables must be of the same sectional area. He was referring to cases of bitumen cable, as compared with a paper insulated cable, where, for the same loading capacity the respective sectional areas were different.

He agreed with Mr. Horsley that where possible the duplicating of shaft or slant cables formed a part of the ideal cable lay-out of a colliery, with a view to ensuring continuity of supply. He thought also that for the larger sizes of cables, say of .5 sq. in. sectional area, it was advisable to run duplicate conductors having the same total loading capacity as the one large cross-section cable. This was necessary from a conductivity point of view as well as from convenience of handling, jointing, etc.

He was of opinion that the use of composite disconnecting cable boxes was a step in the right direction, as they keep and protect the insulation of the cables whilst rearrangements or extensions are being carried out. The lecturer's remarks on circuit breakers and fusible cut-outs were well merited and should be borne in mind. Mr. Richards was afraid that the time incidence of the operation of a fuse received very little consideration, likewise the rupturing capacity of a switch and fuse unit. With reference to the four figures showing the variations likely to be met with in small colliery installations, he thought Mr. Horsley would be amply repaid for the trouble he had taken in connection with this paper, if every colliery electrician were to put down his colliery lay-out on paper, and compare it with the lecturer's; bearing in mind the other subject matter of the paper, and keeping to the lines and suggestions indicated. Progress would then be made in the prevention of that bugbear of the use of electricity in mines, viz., dangerous currents.

Sir ARTHUR WHITTEN BROWN said he was greatly indebted to Mr. Horsley for his most valuable paper, valuable alike to the colliery electrical engineer and to the manufacturer. He was very glad to note the stress which Mr. Horsley laid upon circuit breakers. He rather read into Mr. Horsley's remarks an aversion from fuses. Fuses underground or on any important circuit, appeared to him to be out of place. In speaking of circuit breakers, Mr. Horsley had mentioned a point which was usually lost sight of, one which Mr. Richards brought up, viz., the question of rupturing capacity. In almost every instance it was the rupturing capacity which determined the size of the circuit breaker. Very frequently a circuit breaker controlling a 500 KVA circuit had a rupturing capacity over 300,000.

With regard to differences in circuit breakers as to speeds of break, head of oil, etc., he said this was quite likely to occur, but all reputable manufacturers' circuit breakers would still have their rated capacities. The factors in design which govern rating capacity were not yet fully understood, and manufacturers have arrived at the breaking capacities of their circuit breakers by testing to destruction. The circuit breakers put forward by reputable manufacturers would break up to their rated capacity provided they were properly maintained, and the rupturing capacity was that which the switch could break three times in succession. It could not be counted upon to break again unless the contacts were attended to and the oil changed.

Mr. TANNER expressed pleasure with the moderate tone and the sympathetic attitude, with which Mr. Horsley had dealt with his subject, thus shewing a full understanding of colliery difficulties, and the interpretation of the Electricity Rules. Mr. Tanner said he well remembered a phrase used by Mr. Horsley, during discussion, at a previous meeting in Swansea, viz.: "Is it a good engineering job" and that was the keynote of this paper: good mining electrical engineering jobs, or practice, would fully meet with the requirements of the Electricity Rules.

The essentials of colliery electrical work are: good design and workmanship with sensible supervision, and operation: not necessarily elaborate foolproof gear placed at the mercy of careless or incompetent people He would like to see the Mines Department publish recommendations or model specifications, in conformity with the Rules, for mining electrical work. They would be invaluable as a guide to colliery people generally.

Referring to Fig. 2—the diagram shewing ring-main cables linking surface, pit bottom and pumping station in the shaft—and Mr. Horsley's recommended points for the insertion of overload protection for the smaller cable, Mr. Tanner stressed the importance of having a definite and reliable means of communication between these switching points, and a full understanding between the operators of such switches, and between the electricians who may have to work on any particular isolating links, or portion of the cables. Otherwise there was a positive danger when cables could be made alive from either end.

With regard to cable breakdowns, Mr. Tanner said he considered they were more often due to mechanical damage than to the effects of moisture. He liked to think that colliery electricians were very careful in making and sealing their joints, thereby minimising moisture effects, and they looked to the colliery management and officials to help in preventing mechanical damage.

With regard to Fig. 3 and temporary branch cables: he strongly advocated switches to control each branch, because of the increased safety and great convenience in working. Any one branch cable could then be freed, if wedged or buried, without interfering with the supply to the other branches. With portable machinery this was very desirable and medium pressure switchgear would not be very expensive, since the switch would take the place of a disconnecting link-box.

Mr. Tanner said he did not like the use of fuses on three-phase circuits, especially in places where motors may be left running unattended, owing to the possibility of one fuse blowing and the gear continuing to run on single- or two-phase, with possible disastrous results to the motor or transformer.

Mr. HANNAH said he had been looking forward to hearing this paper and was very pleased to be present. He had been enquiring for some time for improved methods of slinging cables so that they would not suffer mechanical damage from falls of roof or from journies coming off the roads. It was from this source and not from moisture that most of the troubles arose in the collieries he knew. He had rather hoped that Mr. Horsley would have suggested methods of overcoming these difficulties; if the choice of method were to be left to the colliery managers he was afraid it would be rather a hopeless affair. Nor had the cable manufacturers helped them in this respect. In the old days cables with jute coverings were very much larger in diameter than present-day cables with paper dielectrics and owing to the cushioning effect of the larger diameter outside coverings the cables stood up much better to mechanical damage.

The question of leakage protection was a very interesting one but the fitting of leakage protective gear to old classes of switchgear was rather a tedious business. He hoped Mr. Horsley would give them some information regarding the application of protection by current limiting reactances and regarding the results obtained by inserting resistance between the neutral point and earth in earthed systems.

Mr. E. F. COPE congratulated the author on his setting out so clearly the minimum requirements to comply with the Regulations for protecting cable; and enquired why it was necessary to isolate a feeder immediately an earth fault occurred on it. Under some conditions there could be no greater danger than under the earthed concentric system which was permitted under the Regulations and he was sure that the electrician would have a bad time with the mine manager, if he cut off the power supply to a district in the middle of a working shift, under these conditions, when it was possible to carry on and finish the shift before locating the fault.

It was fully time that close attention should be given to the rupturing capacity of switches for it had been his experience of various makes of circuit breakers of 10 amp. capacity which were used to protect lighting circuits supplied off a 500 volt D.C. heavy power mains, that when a fault occurred on the lighting circuit the circuit breaker operated and isolated the fault from the system, the circuit breaker had been partially destroyed in doing so. In reading the paper one gathered the impression that circuit breakers were to be preferred to fuses; Mr. Cope had the same preference although circuit breakers were not immune from misuse. He had come across an instance a few weeks ago, in the case of the supply to an electrically driven coal cutter. The gate end switch which was made by a firm of international repute was set at 70 amps. with a 6 secs. time lag, the circuit breaker protecting the supply to the gate end switch was set at 80 amps. 10 secs. lag. The fault was that the substation switch operated in case of overload on the machine instead of the gate end switch and since this entailed a walk of 300 yards, it caused unnecessary delay. On enquiry it was discovered that the machine operator had discovered that when the gate end switch was put in and only the sparking tips were in contact that the overload plungers did not trip the switch, so they made a contrivance to hold the switch in that position and so cut out all the automatic features.

He could also support the author in advocating the use of cable coupling boxes when using electricity in a machine-mined district, as they simplified the installation and the removal of cables when required, and enabled all the work of fitting the coupling boxes to be done on the surface and the cable taken down the mine ready for use.

Mr. ASHTON BREMNER thanked Mr. Horsley for his excellent paper, which he regarded as the specification of a consulting engineer who knew all the requirements of a colliery. Many small collieries did not consider it necessary to employ a consulting engineer and eventually found that they did not know what was required. This paper indicated to them the minimum that they should have and exactly how to provide for it. He hoped the paper with diagrams would be fully published in *The Mining Electrical Engineer*.

Mr. T. B. STANAWAY.—The conditions under which a cable would have to work deserved more careful consideration than was usual. Impregnated paper, owing to its high dielectric strength and the permanent nature of its constituents, is nowadays in almost universal use as a dielectric for main cables. It is, of course, hygroscopic and must, therefore, be protected from moisture by means of some sort of impervious sheathing, generally lead. Wherever this sheathing is broken, as at joints, or at the ends of the cable, the dielectric must be protected with a box or sealing end filled with compound. For extra high voltage cables, paper is the only insulating medium possible in the light of our present knowledge. It is well known that the ozone developed in the presence of high pressure conductors causes rapid deterioration of india-rubber. Paper, however, is quite unaffected.

As would be seen from the tables of maximum permissible currents in cables, drawn up by the I.E.E., paper insulated cables will carry a much larger current than rubber cables of the same size, because they will stand up to a much higher temperature rise. Vulcanised bitumen cables are preferred by some engineers for mains use, presumably owing to the fact that the vulcanised bitumen dielectric is non-hygroscopic and jointing is, therefore, simpler and less expensive. They suffer, however, from the disadvantage that they cannot be run at such high temperatures as paper cables, and that if they are seriously over-heated, the cores may become decentralised. They are used principally in mining work, and in situations where the cables are likely to be exposed to acid fumes or solutions. The bitumen dielectric being non-absorbent, no lead sheathing is required, and bitumen cables are, therefore, lighter than paper cables, for which reason they are largely used for pit shaft work. Bitumen, however, is affected by alkaline waters, a point which should be watched in cases where the installation of vulcanised bitumen cables is under consideration.

Present practice tends to the use of wire for the armouring of power cables, although some sizes of low pressure cables, chiefly service cables and distribution mains, are usually armoured with steel tapes. This tendency is due to the fact that the Electricity Commissioners will accept a suitable wire armouring in place of the copper Board of Trade Earth Sheath, necessary with certain other classes of extra high voltage cables, and also to the fact that wire armouring supports the cable when, for any reason it is subjected to tensile stress.

Vulcanised bitumen sheathed cables differ from solid vulcanised bitumen cables in that they rely for their insulating properties on a paper dielectric, the bitumen sheathing being employed instead of lead to protect the paper from moisture. In this type of cable the high dielectric strength of paper is combined with the relative lightness of bitumen, the use of lead being avoided with a consequent saving in total weight.

Mr. HORSLEY, in reply to the discussion, said he was very gratified by the variety and extent of the discussion. Referring to the point raised by Mr. Yates where the main cable is .4 and the branch is .05 he would suggest that such a case should be dealt with by looping the big cable into the bus-bar chamber of the switch controlling the small cable in the manner indicated in Fig. 2 at the pump inset. The composite cable junction box shewn in Fig. 5, would, with some modification also meet such a case, but less perfectly.

Mr. Yates had also referred to Reg. 131 (e), and had suggested a watchful switchboard attendant with his eye glued to the leakage indicator, who observes a leakage to earth on the controller of an inbye motor and promptly trips the main cricuit breaker, cutting off all power from the pit. Mr. Horsley indicated that if there were adequate local protection that would act and relieve the switchboard attendant of his dilemma. It happened sometimes that the main circuit breaker did not wait for the switchboard attendant, but would cut the whole mine off when a fault occurred. It would be possible to suggest means whereby the switchboard attendant could make a quick test to determine whether the fault that tripped the circuit breaker persisted before reclosing the breaker; for example, by connecting a lamp or an indicating instrument across the switch gaps, on each pole or phase, in series with the line first successively and then simultaneously. This would indicate and distinguish a short circuit and an earth fault.

Mr. Richards had referred to the rupturing capacity of circuit breakers and fusible cut-outs and suggested that there was need for standardisation. As Sir Arthur Whitten Brown had pointed out, this subject was engaging the most serious attention of the Electrical Research Association at the present time. Experiments had been made through the good offices of the N.E. Coast Electrical Supply Co., to determine the factors governing rupturing capacity. The Power Company had placed plant of large capacity at their service, and some very valuable information was obtained. For the present the user must rely upon the reputation of the manufacturer. Mr. Richards had also touched upon the question of atmospheric disturbances, and suggested that the cable going into the mine would itself provide the requisite capacity, but it is desirable to keep these disturbances out of the pit. One of the best means of ensuring that the underground plant shall not be subjected to such abnormal stresses is to introduce a transformer between the overhead line and the pit installation. Mr. Richards had also referred to the high cost of providing discriminative leakage protection on a direct current system: Mr. Horsley regretted that he could not help him there: insurance must usually be paid for. He did, however, know of collieries where such leakage protection has been used for some time. The first of these installations was that at the Gatewen & Plas Power Colliery, North Wales, and, he believed, the extra cost there was in the neighbourhood of £100, comprising switchboard details and selective protection for several branch circuits underground.

With regard to the difference in current carrying capacity of bitumen and paper insulated cables, that difference may not have been recognised in the past, and Mr. Horsley said he was not sure that it was of very much value for medium pressure circuits, because voltage drop usually determines the density at which the cable could be run. It was, however, perfectly justifiable to adjust the automatic protection in accordance with its carrying capacity; also it was permissible to reduce the sectional area without providing automatic protection if the safe continuous loading of the cable were not reduced.

Sir Arthur Whitten Brown had read into the paper an aversion from fuses, and Mr. Horsley wished to qualify that. His objection to fuses was to the fuse as it is often applied in collieries to-day: he was sure, and had said so in the paper, that there was undoubtedly a useful field for fuses, not only in collieries, but generally in connection with the supply of electricity: but he had in mind fuses of improved design, of large rupturing capacity, and close rating. There was an alternative available in the use of added reactance on A.C. systems, to limit the short circuit current. With regard to a colliery manager's possible objection to the interruption of service while the electrician is looking for a fault, adequate subdivision of circuits would reduce these delays.

Referring to Mr. Tanner's point about the danger of working upon ring main circuits, the only effective precaution lies in earthing the circuit before the conductors are handled, and in earthing by means which entail no danger to the operator. The Mines Department Circular 23 was directed to this matter and it should be studied by everybody concerned.

With regard to Mr. Tanner's statement that the majority of cable faults were caused by mechanical means rather than by moisture, doubtless many colliery cables do suffer mechanical injury; but, where falls of roof are troublesome, in a roadway the cable might be laid in a trench or the trouble might be tackled at its origin by adopting steel arching. Mr. Horsley said that he thought, however, that the cable makers were sometimes blamed for mysterious failures of insulation which were really due to other causes, such as lack of effective sealing of the dielectric.

Mr. Tanner had also pointed out that where fuses were used on a three-phase circuit, this may result in single phasing. Mr. Horsley suggested that this particular trouble would be less likely to occur were the fusible cut-out to be of better design and properly cared for. Fuses often blow because of bad contact or unskilful replacement, and he would not on that account exclude fuses from consideration.

With regard to the use of reactance in the line, or of resistance in the neutral, to limit the fault current, the former is effective under all conditions, the latter only in case of a single-phase fault to earth: he could see no advantage in adding resistance in the neutral in a small installation, it is desirable in the case of a very large installation when plant of large capacity is used; and it is installed where leakage protection is used, in the hope that the leakage device will clear a single-phase fault before it becomes a short circuit. It does not, however, enable one to instal circuit breakers of smaller rupturing capacity, because there is always the possibility that the fault may develop into a short circuit.

With reference to the relative advantages of paper, rubber, and bitumen cable, paper has the advantage of permitting a much higher current density but, as already pointed out, the drop in pressure usually determines the current density at which cables can be used in mines. Tape armoured cable is quite useless for resisting tension and for colliery purposes the electrical resistance of tape armouring is far too high: moreover, said Mr. Horsley, tape armour does not resist crushing any better than does wire armour. With paper cable not only is it absolutely essential to seal the dielectric where the cable is cut, but it is also necessary to earth the lead sheath very carefully. If the lead sheath be not earthed it is almost certain to be damaged by the action of small leakage currents. There is also the possibility, in certain conditions, that the lead may become crystalline and let in moisture. He held no brief for paper cables, or otherwise, at collieries, as the choice of cable depended upon the working conditions. For example there is a particular problem in connection with paper cables which has already been experienced in South Africa where there are very deep shafts; in some cases the hydro-static head on the shaft cables was sufficient to cause the lead sheath to be burst by the impregnating oil in the paper. This difficulty had been overcome, he understood, by special design and by the use of paper impregnated with a wax that is not fluid at normal temperatures.

MIDLAND BRANCH.

The monthly meeting of the Midland Branch was held in Mansfield on Saturday, November 24th, 1928, Mr. R. Wilson in the chair. The following were elected members of the Branch: E. Hawkesley (Student); John W. Burgoyne (Member); George M. Tordoff (Member).

It was arranged to hold the next meeting of the Branch in Nottingham on Saturday, December 22nd.

Mr. R. Wilson then delivered his Presidential Address.

Presidential Address.

R. WILSON.

Six years ago when you honoured me by electing me your President, you gave me the opportunity of presenting for your consideration what I termed to be a few thoughts on Mining Electrical Engineers and Mining Electrical Engineering. To-day, once again as your President, I have a similar opportunity and propose therefore to review the period which has elapsed since my last year of office, having regard in particular to some of those remarks which I thought fit to make in my last Presidential Address.

At that time the items of special interest to which I called attention were: (1) the possibility of a public supply of electricity from the colliery generating plants; (2) the urgent necessity for the immediate increase of facilities for acquiring adequate technical training in this part of the country; (3) the necessity for considering the advisability of Compulsory Certification for Colliery Electricians. In reviewing these particular items of interest I have been impressed by the remarkable progress which has been made, and which continues to be made in matters pertaining to mining electrical engineering.

Public Electricity Supply.

Dealing with the first item: the possibility of a public supply from the colliery generating plants. In my opinion, one of the most important events in electrical engineering that has occurred in this country for some time was the passing into law at the end of 1926 of the Electricity Supply Bill.

Whether the objects which the Government had in view will be best achieved by this particular bill or not is a point which I do not intend to discuss, but I do consider that the passing of the Bill proves that the people of this country fully realise how essential it is that a cheap and ample supply of electricity should be available for all purposes.

It would take too much time to consider the whole of this Bill, though might I suggest that it would easily form the subject of a paper for one of our meetings? There is, however, one clause (No. 21) which is of particular interest to the owners of colliery generating plants and those who operate them.

Clause No. 21 reads as follows: "The Board (that is the organisation which has been formed to operate the Bill) and any company or person producing electricity by means of the utilisation of water power, waste heat, or otherwise, may enter into arrangements for the purchase by the Board of any surplus electricity which the company or person may be able to dispose of on such terms as may be agreed, and the Board may be authorised by the Electricity Commissioners to exercise such powers (including the power to break-up roads, railways and tramways) as may be necessary for the purpose of conveying such electricity."

I do not consider it difficult to visualise what this clause may ultimately mean. It certainly makes it possible for very much larger outputs of electricity from our colliery plants for public services than are now available, and at the same time without the responsibility, financial or otherwise, of the disposal of those outputs. Might I remind you of the paper read by Mr. Morley before this Branch some months ago and you will appreciate the possibilities of this Bill and Clause No. 21 in particular.

Technical Education.

Referring to item No. 2: the urgent necessity for the immediate increase of facilities for acquiring an adequate technical training in this particular part of the country. The opening of the new buildings of University College, Nottingham, by H.M. The King a few months ago, and the opening of the new Technical School in Mansfield a few weeks ago, are incidents which indicate that the Educational Authorities do realise the necessity to which I have referred.

Certification of Mining Electrical Engineers.

The next and last item: the necessity for considering the advisability of compulsory certification for colliery electricians. This is a matter which will be quite fresh in your minds, as it is only a few weeks ago that you expressed agreement that compulsory certification should be adopted. Six years ago I ventured to express the opinion that compulsory certification would be an advantage both to the colliery electricians and to the coal industry, and I have no hesitation in stating that my opinion remains unchanged. So much then for the past.

I believe that a certain amount of satisfaction can be derived from a survey of the past, but the question which is of more importance is: What of the future? As you are all so well aware, the coal industry with which we are all so intimately connected is passing through a period which is without parallel in its history. The prices which are to be obtained for coal are low; wages of the employed are also low; and the output of the collieries in our own district is not more than 75% of the maximum possible output. This is truly a deplorable state of affairs, and whilst it is not my intention to suggest that I have a remedy, I do claim that there is one factor which, if given the opportunity, can effect some improvement, and that factor I would define by the phrase: "Give the Engineers a chance."

The necessity for the production of cheap coal—caused by such factors as the increasing output of coal abroad, the use of oil as fuel, the development of hydro-electric plant both in this country and abroad, and the continual improvements in the methods of using coal—is being met slowly but successfully by what is termed machine mining. Machine mining might well be defined by stating that it is the application of the principle that manual labour should be reduced to a minimum, or even displaced by the intelligent use of machinery wherever possible. In an address of this description I could not attempt to give a detailed description of all that machine mining implies. But it can with every confidence be claimed that an efficient system of machine mining does result in a greater output per person employed, a decrease in the length of coal face that is necessary to be opened out for a given output, together with a consequent reduction in the length of roads underground, with their cost of maintenance. Mining engineers are realising the truth of what has just been stated, and it is to the electrical and mechanical engineers that they have to look to for the manufacture, installation, and maintenance of the machinery necessary. The demand for this machinery can, and is, being met in a manner which, in my opinion, is creditable to all concerned.

Problems of particular interest, which call for high degrees of technical and practical skill and experience are constantly arising, such as the development of the high torque type of squirrel cage motors; and fool-proof, safe and reliable systems of remote control for coal face machinery. There is also the matter of the design and construction of a satisfactory type of trailing cable for portable machinery; and many other problems of a like nature.

Trailing Cables.

Might we consider the question of trailing cables for a moment or two? Those who have the responsibility of taking charge of machines which necessitate the use of trailing cables will appreciate the interest which the Mines Department is taking in this matter. We have the report of H.M. Electrical Inspector of Mines suggesting the use of pliable armoured trailing cables under certain conditions. There has been also the suggestion that some attempt should be made to reduce the number of types that are now manufactured, and to make some attempt to standardise the types. This is all to the good. Personally, I am of the opinion that there is a tremendous amount of work to be done before the perfect type of trailing cable is evolved, and the time spent on the preparation of a paper on trailing cables would be well worth while.

The Work of the Association.

To the mining electrical engineer who takes a real live interest in his job, the whole business of mining electrical engineering was never so difficult, but yet so full of interest and possibilities. The demands which are being made are so heavy and in many cases the reward —financial at any rate—so small that many are asking the question: "Is the labourer worthy of his hire?" To many the matter is so acute that suggestions have been made that our Association should deal with it. That, however, is not possible. The Association of Mining Electrical Engineers is purely a scientific and technical organisation, and though one of its avowed objects is to elevate the status of those engaged in the application of electricity to mining, yet negotiations for salaries, wages, etc., are outside its scope. At this stage I would like to say just a few words about our own Branch. We of the Midland Branch have always believed that we have amongst our members a larger proportion of actual working colliery electricians than any other branch, and consequently the papers which have been read before the branch have been of a more practical nature than the average in other branches and, therefore, of more practical benefit to the members.

As the chairman of your Branch Council I have some little responsibility for the selection of suitable papers for our meetings, and I want to appeal, particularly to the younger members, for offers of papers for this session. The benefits to be derived from the preparation of a paper are, in most cases, ample reward for the trouble taken; at the same time there is the possibility of being awarded one of the prizes which are offered by the Association for papers of merit. You will remember that last year one of our members, Mr. Pidcock, was successful in gaining one of the Association prizes. I can assure every young member, who will attempt to favour us with a paper, of a most sympathetic and helpful consideration.

There is just one other feature of our meetings to which I would call your attention, and that is the discussion of problems. There is not one amongst us who does not frequently come up against problems of either a practical or technical nature, and I suggest that if these problems were brought to the meetings for open discussion, nothing but good could result.

In conclusion I would express my appreciation of the honour you have conferred upon me in electing me as your President, and I can assure you that given your support we can look forward to a most useful and interesting session.

Mr. J. B. G. NORTHCOTT, in proposing a vote of thanks to the President, said they all appreciated very much what Mr. Wilson had said to them. He had noticed that day in the editorial comments in *The Mining Electrical Engineer* reference was made to the Presidential Addresses of the various Branches, and it was mentioned that speaking generally they were in a very optimistic vein. Mr. Wilson had referred to the progress made during the last few years with regard to educational facilities, power distribution, and certification, and the points he brought out as regards the progress of these particular activities should make them really optimistic.

Mr. W. WYNESS said he had great pleasure in seconding the vote, and was quite sure they all felt, as he did, that they had listened to a very interesting and helpful address, and one worthy of much consideration. They had in Mr. Wilson one who was anxious for the success of the Branch, and—with the support of the members—one who would do all he could to promote that object.

The real object of anyone joining this Association should be not "what can the Association do for me, but what can I do for the Association." If all were imbued with this idea they would gain, and it would fulfil the objects of the Association. Mr. Wilson had also mentioned the question of status, which was so often alluded to. Mr. Wyness said he felt it to mean that this could only be raised by what one did for one-self. If everyone tried to raise the status of his own efficiency that would benefit the Association, the members individually and the whole.

SOUTH WALES BRANCH.

Modern Methods of Steam Raising—with Special Reference to Pulverised Fuel.

SIDNEY B. HASLAM.

(*Paper read* 10*th November,* 1928).

The main object of this paper is to provoke a discussion and to obtain from the members of this Branch of the Association practical information of their several experiences in steam raising. It is a well-known but none the less lamentable fact that even up-to-date methods of steam raising are wasteful, and it is only in few stations that more than one-quarter of the power stored in the raw material is extracted and utilised in the finished product.

None the less, engineers and scientists have of late years given much attention to the subject of fuel technology with undoubted good results, but there is still much to be done before the present-day waste is eliminated. It does not require much imagination to visualise the day when it will be a penal offence to burn coal in any boiler or open grate. Low-temperature carbonisation, bye-product recovery, and other methods whereby the forces stored in coal are utilised to the best advantage will become general, and water will be evaporated by the heat of the waste gases supplemented, if need be, by oil or pulverised fuel. Possibly, in a few more years, the gas turbine will become an established and commercial fact, and boiler plant will gradually become obsolete. Even to-day, in the large electrical schemes, some consumers find it advantageous and economical to maintain a small station with Diesel engines to operate during the heavy loads and to flatten out the peaks. The benefit, if taking power on a maximum demand, will be obvious. This, however, is a digression, and in opening the subject of the paper a few remarks on the early methods of steam raising may not be out of place.

It was in the latter part of the eighteenth century, about 1792, that James Watt, when he entered the field of practical engineering, found the combustion of coal for steam raising very crudely carried on.

At that time Cornwall, with its extensive, well-developed, but wet mines was the chief steam raising district: the need of pumping plants being considerable.

In those days the boilers used were large cylindrical affairs, under which many tons of coal were burning at one time. One such boiler at the Dolcoath mine actually had a grate 22ft. × 7ft., and carried 30 tons of coal in a fire 7ft. thick.

The instructions given by Watt in those days for the proper firing of bituminous coal are of great interest, as his advice is, even to-day, as sound as anything can be. He recommended that coal be piled upon the dead plate. There were no fire doors, the pile of coal serving as the door. The heat of the fire beyond caused the volatiles to be driven off gradually, while the pile, being porous, allowed air to be drawn through it, mingling with the gas and burning with it. Thus, in time, the pile became partially or wholly coked. This fuel was then pushed onwards over the more consumed fuel, where it gave off more gas freely and at the same time copious supplies of air came in through the now unclosed furnace opening. This opening was then closed with fresh supplies of green fuel, and the cycle of operations repeated. From this it will be noted that Watt advocated the coking system of firing.

Following this early type, Trevethick introduced an internal tube, primarily to provide more heating surface, but later on this tube was enlarged and the fire-grate placed inside to form what is known, even to-day, as the Cornish boiler.

The next development may be put down to Fairbairn who, early in the nineteenth century, designed and built the double tube or Lancashire boiler, but in both these modifications it will be remembered that the arrangement of the fires and the course of the gases relative thereto remained the same.

The next step was, to an extent, a retrograde one, and one which is still a source of trouble. It was found that a boiler would generate more steam if the coal was spread over the fire instead of being coked on the dead plate. Combustion was certainly more rapid, but smoke was the result, and it is this fact that is really the starting point of all modern development.

These few remarks may serve to show that though boiler design has been altered and many economies discovered and used, the fundamentals of steam raising are practically the same to-day as they were so long ago. We must, however, here refer to pulverised fuel and gas firing, as the first genuine departures from these fundamentals, and whether one agrees with these ideas or not one must admit the possibilities.

Before going further into these and other modern methods a few remarks on the chemical side of coal combustion may not be out of place. Coals vary greatly both in composition and in behaviour during combustion. The combustible elements are, firstly Carbon, then Hydrogen and Oxygen in chemical combination with carbon and each other, while the remaining constituents are Nitrogen, Sulphur, and the various mineral impurities known as the ash.

It will be realised that the most important factors in the combustion process are the carbon or carbonaceous constituents of the fuel, and the oxygen of the air, but one also has to deal with hydrogen and nitrogen chiefly in combination with other elements, and also sulphur which occurs as an impurity in most coals.

These elementary bodies yield in combination with one another, compounds which may be solid, liquid or gaseous at the ordinary temperature, and the whole question of combustion, evaporation, and fuel economies revolves round the combinations which occur on the grate and in the flues.

The various combinations are as follows: Carbon (C) and Oxygen (O) yield Carbon Monoxide (CO) and Carbon Dioxide (CO_2), and here it must be emphasised that the CO is a combustible gas, and will unite with more oxygen (if available) to form CO_2.

Hydrogen (H) when burnt in oxygen or air, yields water, usually in the gaseous state as steam; more important, however, are the combinations of hydrogen and carbon, which yield what are known as the hydro-carbons, and which play an important part in the combustion process. The more important hydro-carbons are: Methane, CH_4; Ethylene, C_2H_4; and Acetylene, C_2H_2.

Nitrogen (N) serves no useful purpose in the combustion process, being present only as a diluting constituent of the air. It is not a supporter of combustion and does not here combine with carbon or with oxygen.

Sulphur (S) is present as an impurity in most coals and burns in oxygen with the production of Sulphur Di-oxide (SO_2). The amount is, however, small and as it does not mean the generation of any large amount of heat it is not usually considered. In the early days the presence of sulphur was important, and gave one of the only means then known of testing combustion. In combination with hydrogen, sulphur forms a gaseous compound with a very distinctive odour, known as sulphuretted hydrogen (H_2S), and the presence of this gas in the waste gases is a certain sign of imperfect combustion. If sufficient oxygen were present there would be no H_2S, but H_2O and SO_2.

To achieve proper combustion it is necessary that the fuel be raised to the temperature of ignition, that there be sufficient oxygen for complete combustion, and sufficient time for the combustion of carbon and hydrocarbons to take place before the gases become cooled.

Now the temperatures of ignition may be taken as follows: Acetylene, 580° C; Ethylene, 592° C.; Methane, 667° C; Carbon, 700° C. It will thus be seen that the hydro-carbons (usually known as the volatiles) are liberated first, and we will consider what must happen to secure perfect combustion. Oxygen must be provided to combine with these hydro-carbons to form carbon dioxide (CO_2) and water (H_2O), and as the combustion is extremely rapid, a matter of a few seconds only, it is necessary to provide an excess of air to ensure complete combustion, otherwise the time would be insufficient to allow for complete chemical union. The same remarks apply to the liberation of the carbon, which takes place when its own ignition temperature is reached. The matter of the excess air is important and will be referred to later, but meanwhile the following figures will show the heats of combination and combustion: Acetylene, 3035 B.T.U.; Ethylene, 3040 B.T.U.; Methane, 3335 B.T.U.; Carbon Dioxide, 14,650 B.T.U. The combination of hydrogen and oxygen is also marked by the liberation of 7287 B.T.U. and the production of water vapour.

In passing, reference might again be made to the combustion of sulphur; if insufficient oxygen is present the hydrogen is not completely combined, and some portion is free to combine with the sulphur, producing sulphuretted hydrogen and thus proving, as mentioned before, imperfect combustion.

Referring now to the combustion of carbon in oxygen, the figure given above for the heat generated when carbon is burnt to carbon dioxide (CO_2) represents perfect combustion, but if insufficient oxygen is present carbon monoxide (CO) is formed, and the resultant heat is only 4450 B.T.U., a loss of 10,200 B.T.U. Hence again, the need of excess air to ensure the formation of the dioxide. This also applies in the case of the hydro-carbons, when lack of oxygen means the formation of carbon monoxide and the liberation of free hydrogen instead of carbon dioxide and water vapour.

It is also necessary that these chemical combinations and changes should take place before the gases are cooled too much, and this means an unavoidable loss so far as the boiler is concerned, because the gases must leave the flues at a temperature which still contains much useful heat.

We therefore establish as fundamentals for fuel economy the following:—

(A) Means of raising the fuel to the proper ignition temperature and of driving off all volatile gases, hydrocarbons, and amorphous carbon.

(B) Means of admitting and regulating the admission of air, and therefore oxygen.

(C) Means for extracting the maximum amount of heat from the gases ultimately formed.

As this paper is chiefly concerned with (A) it is proposed to deal briefly with (B) and (C), returning to (A) later.

(B) For many years the question of the air was scarcely considered, and it was usually taken that provided sufficient oxygen was present to give a high rate of CO_2 the maximum economy was being obtained.

The extremely rapid process of combustion makes it necessary to provide an excess of air, otherwise it would not be possible for all the carbons to come into contact with the oxygen necessary for their combustion. A figure of 40% excess air has usually been taken as a fair average. It must be realised that all this air coming into the furnace tends to lower the temperature and that the losses due to heating up this air are considerable, therefore any modification of the system of firing which reduces the volume of air will mean economies. This point will be referred to again.

Of late years the preheating of the air has come into very general practice; at first only the waste gases were used for this purpose, and the air heated to about 300 deg. F., but lately much higher temperatures have become common and 600 deg. F. and even 700 deg. F. are in operation to-day. It should, however, be noted that care must be taken to avoid the burning of the grates.

The question of draught is one which requires careful consideration, and means of regulation are imperative. Even to-day, in many cases chimney draught is in use with damper regulation only, but in an up-to-date plant induced or forced draught fans are adopted, and the closer regulation possible well repays any extra outlay or running costs.

It must be apparent that when the load is variable and liable to sudden demands or peaks it becomes necessary to have means of increasing combustion very rapidly, and to achieve this it must be possible to provide ample oxygen.

(C) Under this fundamental rule may be included the type of grate and boiler, size of grate, method of stoking, arrangement of flues, and the provision of superheaters and economisers and feed water heaters. The advantages and disadvantages of these various aids to efficiency are well known, and it is not proposed to dwell on this rule, but in view of later remarks it should be borne in mind that one of the defects of mechanical stoking is that it will not respond to sudden and erractic demands for steam—in fact, to give the best results a uniform quality of coal, with uniform thickness of fire, speed of grate, and admission of air becomes necessary.

Superheating also presents considerable advantages, whether partial superheat, to give dry steam and to prevent condensation losses in long and exposed pipe lines, or full superheat, up to 700 deg. F., as an aid to efficiency; in which case, of course, the prime mover must be built for the purpose, otherwise lubrication troubles will ensue.

Economisers and feed-water heaters are also essential in modern and efficient plant. The temperature of the waste gases varies with conditions, but 575 deg. F. may be taken as a fair average; this can be reduced to 400 deg. F. and in consequence the feed water heated up to about 250 deg. F.

(A) We now come to the questions raised under rule (A), and to consider the results of using the fuel in pulverised or powdered form. First of all we must ask ourselves: What is pulverised fuel? The answer is comprehensive: Any carbonaceous fuel high or low grade which has been ground to an extremely fine powder after the moisture content has been practically eliminated.

Let us remember what has been stated previously about combustion and the need of excess air, and realise first that a lump of coal, say one inch cube, exposes a surface of six square inches, while the same piece when pulverised to pass through a screen of 200 meshes to the inch, exposes an area of approximately 1200 square inches. It is at once obvious that the amount of excess air required to complete combustion can be considerably reduced, and therefore the heat losses necessary for bringing the air up to ignition temperature are also considerably reduced. From this fact alone the chief claims of increased efficiency for pulverised fuel are drawn. The claims are:—

(1) Less excess air and therefore higher CO_2 contents, and so a higher temperature of combustion; this tends to complete combustion and therefore no carbon loss in ash.

(2) Any class of coal can be burnt efficiently.

(3) Increased flexibility.

(4) Stand-by losses greatly reduced.

(5) Cleaner, better, and more hygienic conditions in the boiler house.

(6) Reduction or elimination of smoke losses.

The disadvantages lie chiefly in the increased cost of production and handling, and the difficulties which have to be overcome in dealing with the ash.

While many of the members have considerable knowledge of pulverised fuel plants, a brief outline of the process may be of interest. There exist to-day two distinct methods of dealing with fuels to be burnt in pulverised form: (a) The Central Storage System, and (b) The Unit System. It will be realised that these methods or systems deal only with the fuel up to the firing point.

The central storage system, as the name implies, covers the treatment of the raw coal in bulk, and demands large and costly additions in plant and considerable alterations to existing boiler houses. It cannot be considered seriously except in the case of new and super power stations, and the author proposes therefore to confine his remarks to the Unit System.

The Unit System, as again is implied by the name, consists of plants each working as a separate unit, in which the coal, as it is pulverised, is conveyed direct to the combustion chamber and the storage of pulverised fuel is dispensed with.

The coal is delivered and dumped into a storage bunker, and as a large or thro coal will usually be used it will be passed through a crusher, breaking it down to a small size about ¾in. to 1in. This is done with two objects, one to assist the final pulverising, and the other to help and improve the evaporation of the moisture in the drier. From the crusher the coal will be elevated and should be conveyed along a short belt passing over a magnetic separator to remove any pieces of iron, etc., which may have got into the coal. From this belt the coal passes to a storage bin and gravitates to the drier.

The Drier will usually be heated by the waste furnace gases, though some are fired independently. The drier will be designed to reduce the moisture in the coal by about 90%, say from 10% to 1%, and the surface must be large enough or the passage of the coal slow enough to do this without increasing the temperature of the coal above 400 deg. F., otherwise there will be a loss of some of the volatile contents. The drier is really a source of considerable loss as the heat required to dry the coal to the determined degree may be equal to as much as 1% of the thermal contents of the coal being dried. From the drier the coal will again be elevated to the dry coal bins from whence it passes to the pulverisers.

Pulverisers are of various types, but opinions vary chiefly between the ball mill and the roller mill. Each has its advantages, but users should consider the following points: (1) freedom from breakdown; (2) low maintenance costs; (3) absence of noise and vibration. These points seem to be best met with a slow-speed ball mill. Incidentally it should be noted that with a ball mill a magnetic separator is not a necessity, as any loose iron or metal substance can do no harm, and as a matter of fact will actually assist pulverisation.

The question of separation in the pulveriser is also debatable, but now most manufacturers seem to have definitely adopted air separation in preference to screens. Screen separation probably gives a larger proportion of extremely fine powder, but air separation provides less chance of the dust escaping to the atmosphere.

The next operation is the conveyance of the powdered fuel to the burners. This can be done either by mechanical or pneumatic means, depending chiefly on the relative positions of the combustion chamber and the pulveriser. While the pneumatic system is much less in first cost than screw conveyors, the latter system is probably the most used and better system where the distance is small.

The fuel has now reached the burner and a paper might well be written on this subject alone. The author does not propose to discuss the various types, but the following points are important, and the burner which best deals with all or most would appear to be the most suitable. (1) Ignition and combustion must be most rapid; (2) any moisture left in the fuel must be evaporated; and (3) distillation must be complete.

Harking back to the early part of the paper the various changes referred to, physical and chemical, now take place at the mouth of the burner, and the burner must be designed to give a reverberatory action.

Distillation commences at about 400 deg. F., and gases and volatiles are driven off, forming smoke. Meanwhile the entering coal particle absorbs radiant heat and increases in temperature. Now the primary air which is admitted with the fuel is only a poor absorber of radiant heat, and will probably have increased but little in temperature when the gases begin to distil. Meanwhile the smoky gases containing carbon particles continue to absorb radiant heat, and the temperature increases till the mixture reaches the ignition point and combustion of the gases begins.

Water vapour and carbon dioxide are now produced and so the combustion process goes on step by step. The rapidity with which the free carbon particles combine with oxygen depends largely on the speed of mixing with heated air. This carbon particle may truly be called coke, as the hydro-carbons and volatiles have been driven off and the speed of combustion of this coke and the consequent length of flame travel are dependent on rapid mixing.

TABLE I.

Percentage of CO_2 in Exit Gases.

Temp. of Exit Gases in Degrees F.	4%	5	6	7	8	9	10	11	12	13	14	15
	Total Percentage of Fuel Wasted.											
400	32.4	26.2	21.8	18.9	16.4	14.9	13.4	12.3	11.4	10.6	9.8	9.2
500	45.	32.7	27.3	23.6	20.8	18.6	16.8	15.4	14.2	13.2	12.3	11.6
600	48.6	38.3	32.8	28.3	24.9	22.3	22.	18.5	17.1	18.9	14.8	13.9
700	56.7	45.8	38.2	33.1	29.1	26.0	23.5	21.6	19.9	18.5	17.2	16.2
800	64.8	52.4	43.7	37.8	33.2	29.7	26.9	24.7	22.8	21.2	19.7	18.5

To appreciate the need of rapid and even violent mixing one should visualise the coke particle as surrounded with inert gases; that is to say, the water-vapour and carbon-dioxide mentioned above, and it is only when these gases are removed that the oxygen can get at the coke. Again this coke takes some time to burn, and fresh supplies of oxygen must be constantly available until complete combustion has taken place; in fact, that particle of coke must come in contact with some 10,000 times its own volume of air before it is completely consumed.

It is therefore essential to rapid combustion that the mixing should be extremely violent, and turbulence in the furnace is an essential factor in the burning of pulverised fuel.

We now come to the question of the furnace, and this is probably the most controversial part of the whole system, as we meet at once different schools, representing different ideas on the subject of high temperatures. As has been shown, not only does the efficient combustion of pulverised fuel require higher temperatures, but these higher temperatures are localised and therefore more intense in some parts of the furnace than in others. Slagging and refractory troubles have for some time been causing considerable trouble, and much thought has been given to furnace design.

Needless to say different designers have different ideas, but it now seems to be an accepted fact that the fuel must be delivered in a downwards direction into the furnace, meeting the secondary air on its downward path and rising to the boiler tubes, thus forming as it were a U-shaped flame.

One advantage of this lies in the fact that the particles of ash in the fuel will fall, and it is usual to provide a water-screen through which these particles will pass to the ash-pit. This water-screen has the additional advantage of preventing fusion and clinker. The secondary air should be preheated to at least 150 deg. F.

Before proceeding to the advantages of pulverised fuel firing the author would like to submit for the consideration and views of the members what appears to be almost an ideal system of combustion, and that is the the combined stoker and pulverised fuel burner furnace. It is generally agreed that for thermal efficiency a mechanical stoker of the chain-grate type is pre-eminent provided—and this is the snag—that the load is constant so that the speed of grate, thickness of fire, and air admission may also be constant.

It is a fact that on a furnace of any given area and height 5lbs. of coal can be burnt, as against 3lbs. of the same fuel in pulverised form with a corresponding evaporation.

Let us now consider the advantages claimed for pulverised fuel, and then combine these advantages with the advantages of mechanical stoking and see whether the combined system does not appeal as the most nearly perfect method of fuel combustion.

The respective advantages claimed are:—

Ability to burn any class of fuel.

The supporters of pulverised fuel firing will claim that any class of coal can be successfully burnt in their own particular system, irrespective of ash and volatile content, but the author submits that this is too wide a claim and that the firing of fuel in powdered or pulverised form is limited economically to soft coal, i.e., bituminous or high volatile coal.

Makers of mechanical stokers will put forward claims of just as wide a nature, and it is quite a debatable point whether or not with at least as equal a right. Actually the author would suggest that with soft coals of high volatile nature the pulverised fuel system might show some economies, but with the harder coals and lower volatile contents mechanical stoking still more than holds its own.

Efficiency.

Here it is claimed to be obvious that coal can be burnt more efficiently in the powdered form, that it is more easily controlled, and that the losses due to the presence of combustible matter in the ash are reduced to the minimum.

If we are to assume that high CO_2 means efficiency then certainly pulverised fuel scores. While it is possible to obtain high CO_2, 14% or 15%, with mechanical stoking under test conditions, it is well-nigh impossible to do so under the varying load obtaining in a boiler house; but with pulverised fuel these figures can be maintained day in and day out. The saving in fuel effected by maintaining a high percentage of CO_2 with a low temperature of exit of the waste gases is shown in the Table I.

Too much excess air, however, may have the effect of lowering the CO_2 contents with a higher exit temperature. Again, a low CO_2 with low exit temperature does not necessarily mean bad combustion, as it may be due to air leaks. Therefore if the CO_2 is low it is not advisable to increase the amount of excess air though on first sight this may appear natural. Rather should the air be reduced and the results carefully considered in connection with the exit temperature. The object to aim at being high CO_2 contents with low exit temperature and the minimum of excess air.

As regards the ash, with mechanical stoking the boiler-house staff would be well satisfied if the combustible in the ash was kept as low as 10%, whereas with powdered fuel even 2% is a high figure.

Flexibility.

Here is probably the greatest point in favour of pulverised fuel, in fact it has all the advantages in this direction of oil firing while being infinitely cheaper.

Banking.

When burning high-class coals this advantage is not so apparent, but with mechanical stoking it is difficult, if not impossible, to maintain a high efficiency on very light loads or no load with low class coal, whereas when using this low class coal in the pulverised form very low ratings can be maintained with high efficiency, and if necessary the furnace can be shut off and started again without any serious losses.

Boiler Capacity.

This depends largely on tube troubles and the condition and treatment of the water. Certainly with pulverised fuel the heat, i.e., the gases of combustion are distributed over the whole bottom surface of the boiler, whereas with mechanical stoking there is more local impingement, but nevertheless it is still to be proved that as high a boiler capacity can be maintained with pulverised fuel.

Automatic Control.

There is no doubt that pulverised fuel lends itself to automatic control, and the author is given to understand that in one station in America automatic control has been extended to such a degree that one operator controls the entire plant.

Charges (Labour and Maintenance).

In view of the above statement it must be taken as definitely established that the cost of labour is less in a pulverised fuel installation; but maintenance costs are not so favourable, and even the introduction of the water screen and air-cooled walls, while of enormous benefit, have not yet reduced maintenance costs to the low level of mechanical stoking. In fairness to pulverised fuel, however, the proviso must be added that the class of fuel will affect the maintenance costs of mechanical stoking, but not those of pulverised fuel firing.

Smoke

Here again there is a distinct advantage in favour of pulverised fuel. Combustion is more complete and a varying load can be met with a proper admixture of air, whereas in mechanical stoking one usually finds that a sudden demand for more steam means a release of hydro-carbons without the immediate provision of sufficient oxygen to ensure combustion.

Cleanliness.

In this connection the author would quote from a paper given by Mr. David Wilson, who stated:—

"The condition of things existing at Messrs. Ford's works at Detroit is such as civilisation will demand for our workmen of the future. The whole boiler-house plant there, consisting of eight boilers, each capable of evaporating 350,000lbs. per hour, suggests a departure from the kitchen to the drawing-room in boiler-house design. The boiler casings and the boiler-house floor are enamelled and the latter is covered with linoleum mats. All the fittings are nickel-plated and there is not a particle of dust to be seen anywhere. The boilers are controlled from two switchboards by two operators dressed in white duck suits."

COMBINED SYSTEMS.

Now let us see whether these advantages are not increased in the combined system of firing.

Ability to Burn any Class of Fuel.

It appears that mechanical stokers can burn almost any type of coal to-day, in fact manufacturers will claim that a chain grate stoker of the compartment type will burn efficiently any solid fuel that can be handled mechanically, whereas, as has been stated, pulverised fuel firing is limited economically to soft coal. On the other hand, if much ash is present the efficiency of the mechanical stoker is reduced owing to the amount of combustible passing over in the residue. It must be realised that with an absolutely even fire and rate of combustion many of the disadvantages of mechanical stoking disappear, and it may be claimed that the combined system will burn just as efficiently any fuel which can be burnt efficiently in pulverised form.

Efficiency.

Actual tests on pulverised fuel have shown 83% efficiency as an attainable figure, and on mechanical stokers with economisers and preheated air, tests have shown efficiencies of over 83% on full load and over 87% on light loads, and this with fuel of a calorific value of just over 13,000 B.T.U.

Flexibility.

Here the advantage is in favour of pulverised fuel as against mechanical stoking, but with the combined system one obtains the flexibility of pulverised fuel with the reliability and steadiness of mechanical stoking under test conditions.

Banking.

The advantages of the combined system are obvious. With high-class coals a light fire on the grate, moving at the slowest possible speed, will give the best results when just keeping up the pressure and the immediate results of opening the burners will meet the demands for steam without the losses which would ensue if the fire on the mechanical grate had to be operated in the usual way. If low-class coals are being used it will be necessary and advantageous to bank on the pulverised fuel burners.

Boiler Capacity.

This would certainly be greater with the combined system, as the general distribution of the gases with pulverised fuel firing is allied to the better circulation caused by the local impingement of the gases of stoker firing just where this circulation is of greatest benefit. It is claimed that evaporation can be doubled by adding one or two burners over an existing mechanical grate.

Automatic Control.

This point certainly seems in favour of all pulverised fuel firing as the control of mechanical stokers cannot be maintained from a distant switchboard. Further consideration, however, will show that this is not the case if the stoker conditions are absolutely uniform, as any variation in the load is taken on the burners, controlled from a distant board.

Labour and Maintenance Charges.

At first sight it would appear that these, especially the maintenance side, must go up with the combined system, and unfortunately there is no data available, but there does not seem to be any real reason why the charges saved on the one side by the reduction of the size of the plant, number of burners, etc., should be exceeded by the charges on the other side. Again it must be remembered that the chief maintenance costs of mechanical stoking are due to the necessity of dealing with a varying load, and these costs would be considerably reduced with the steady load of the combined system.

Smoke.

Even assuming an entire absence of smoke with pulverised fuel this will also be the case with the combined system, as any hydro-carbons not consumed on the grate will be completely consumed in the secondary fire zone of the pulverised fuel.

Cleanliness.

This is probably the only advantage in favour of pulverised fuel. Even though the stoker plant is much cleaner because of the steady load there will be dirt and dust in the boiler house which should not be present in pulverised fuel firing.

To sum up, the author submits that this combined system offers many advantages, and would seriously suggest that owners of steam raising plant with modern mechanical stokers should pause before converting to complete pulverised fuel firing, and when the saving in first cost is taken into account there will undoubtedly be a very good case for the alteration of the furnaces and the installation of one or two burners to take the peak loads, leaving the existing chain grate to carry the main and steady loads.

Pre-Gasification.

Another method of using pulverised fuel is worthy of attention and in the opinion of the author there is a considerable future before powdered fuel firing by pre-gasification, and this system is specially applicable to Lancashire boilers. By this method pulverised fuel is subjected to a preliminary process of gasification by partial combustion in a relatively small chamber of special design. The gaseous products so formed, which of course consist of the volatile constituents of the coal together with a large proportion of carbon mon-oxide will be admitted directly to the existing combustion chamber or the boiler or furnace together with a sufficient amount of secondary air to complete the combustion in this existing chamber.

It will be appreciated that this gives us a sort of two-stage combustion, and is somewhat similar to the reaction which takes place in ordinary gas producers, but with the important difference that there is no cooling and, therefore, no sensible heat lost. It will be obvious that this cooling cannot take place as the first gasifying chamber communicates directly with the combustion chamber so that these combustible gaseous products are still in the stage of partial combustion while they pass to the combustion chamber where they are mixed with the secondary air and completely fired. The advantages of this method are considerable and in certain cases it appears to form the only practicable method of using pulverised fuel at all.

As has been stated the most serious troubles when using pulverised fuel are found in the combustion chamber itself, where one gets a high velocity steam of fiercely burning coal and air at a very high temperature, while in addition there is a spray of molten ash bombarding the walls of the chamber which has to be dealt with either with a water seal or some other method.

With pre-gasification we have a relatively slow moving volume of red hot combustible gas passing to the combustion chamber and filling it as it burns quickly with the secondary air, and though it may be suggested that in eliminating these difficulties in the combustion chamber we have only transferred them to the pre-gasifying chamber it must be remembered that the conditions in the gasifying chambers are those of a producer and not those of an ordinary combustion chamber. In the first case the amount of air supplied is definitely limited to the quantity which is required for gasification and no more, and the heat released is, therefore, only sufficient to maintain the re-active temperature which for average coal will be found to be about 1200 degs. C.

Owing to this fact it is possible to make the chamber relatively small and to maintain the coal and air mixture in the special state of turbulence which is necessary to effect the gasification process.

It will also be understood that the collection of the greater proportion of the ash from the fuel is effected in this chamber where the changes of direction of the fuel streams during the gasification process will be found to produce the necessary separating action and the ash will fall out of the bottom of the gasifier in the form of dust or as slag, but in neither case will there be any serious effect on the brickwork owing to the limited temperature at which the whole lining is maintained

One objection which will be raised is that this method introduces a further source of loss, but it will be found that the actual loss in the gasifier is not more than 1%, while the loss in radiation including the gasifier and the passage of the gasses to the second combustion chamber will not exceed a further 2%. In fact, it is definitely stated that the heat balance of a Lancashire boiler when fired with powdered fuel by this pre-gasification system will give a nett result of 82%, the losses being as follow:—

Loss in gasifier, 1%.

Loss due to radiation unaccounted for and carbon in the ash, 4%.

Loss in heat of chimney gasses, assuming an exit temperature of 200 degs. C., 12%.

Loss due to power used in pulverising, 1%.

The author submits that this system is well worth careful study.

[By the courtesy of some of the manufacturers and designers of pulverised fuel equipment the author was able to illustrate the paper with some slides, but would like it to be clearly understood that the descriptive matter was not his but that of the manufacturers, and he disclaimed responsibility for any of the statements contained therein.]

NORTH WESTERN BRANCH.

Control Gear for Coal Face Machinery.

WILLIAM REA.

(*Paper read in Atherton, 29th October,* 1928.)

The subject of switchgear at the gate end for use with coal cutters and conveyors has from time to time been investigated by electrical engineers and mining people in technical papers, but generally the detail unit known as the gate end box has been the main feature of such discussions. Gate end boxes have taken various forms and designs, commencing with the simple type of switch and fuses, followed by oil switches with overload and no-voltage protection, these latter being developed further to incorporate a no-volt, no-close device which is energised from the secondary side of a transformer to give a low voltage local earth circulating current. The next step in this direction has been to develop what is known as the remote control gate end box, this being quite the very latest practice, but so far its use has chiefly been limited to controlling the supply of current to coal cutter motors.

These various gate end boxes, particularly the fuse, plain overload, and the overload with earth circuit protection types, are generally well known; but the remote control system having not yet been used so extensively, the details are not so familiar and it will be well to illustrate by means of diagrams one or two arrangements which will permit of comparison being made with the other types.

The Portable Sub-Station.

The tendency today is to lay out mining machinery on a definite scheme of working, and instead of using a collection of gate end boxes, say one for each motor, these gate end boxes being connected to the main supply cable by various forms of cable joint boxes, there is a demand for the development of a portable sub-station, and it is the portable sub-station which will form the main feature of this Paper. The colliery manager is endeavouring very largely to decide on the method he shall work his coal measures and instal plant to suit the scheme decided upon, so that this enables the electrical engineer to provide for the control of the machinery with apparatus which, whilst being flexible, is more or less specially designed for the work it has to do.

The designer, in putting forward a scheme for a portable sub-station for the gate end has many factors to consider. To begin with, the colliery manager usually begrudges space for the apparatus and is not disposed to afford road width or special insets or any other accommodation unless he is absolutely compelled; most electricians know that if apparatus is to be efficient, creepages and clearances are most essential, and when these have to be enclosed in flameproof cases it is impossible to make apparatus with sufficient capacity as small as the mining man would like to have it. The question of the size of the gear is of the utmost importance and is apparent to one who has had a fair amount of gate end experience; so that when the question of space occupied is investigated, a carefully designed portable sub-station has many points in its favour over the miscellaneous collection of gate end switches and cable joint boxes.

The ideal portable sub-station for the gate end would consist of circuit breakers of the solenoid operated type which embody overload and no-voltage features. The circuit breakers, in conformity with the latest practice, being of the air break type and having magnetic blow-out attachments fitted to the main contacts. Contacts fitted with such attachments are well known to have higher breaking capacities and better arc rupturing qualities than contacts not so provided. The overload protective features of the circuit breakers also require special consideration in the fitting of retarding devices or dash-pots and, from the author's personal investigations, if successful operation is to be obtained the dashpot requires to be carefully designed so that it will permit of motors being switched direct on to the line and at the same time allow the overload trip to be set at a value which closely corresponds to the maximum current load recommended by the motor makers.

For the operation of the circuit breakers it is necessary to provide a low voltage operating circuit, so that a continuity of the main earth circuit is essential in order that the circuit breakers are switched off should an attempt be made to withdraw trailing cable plugs whilst machines are running. A main isolating switch is also desirable so that a manual means of complete isolation is available should it be required.

With three-phase earth neutral systems, which are now the most common, an earth leakage protective device is not only desirable in the portable sub-station, but it should be compulsory; however it is no use installing an earth leakage device at this point unless it has a considerably lower operating value than the protective devices arranged with the main oil switches which control the gate end circuits.

Taking these details, that is, circuit breakers, the means of providing a low voltage operating circuit, main isolating switch and earth leakage protective device, and enclosing them in a strong flameproof case, there are all the internal apparatus required for a portable sub-station. On the outside of the case at one end would be mounted a gland for the incoming cable and at the other end glands or plugs and sockets for the outgoing cables to the various machines.

The portable sub-station can be arranged either to slide along the floor or, if desired, wheels can be fitted to suit the track. The apparatus generally requires to be so constructed that uneven floor conditions, inclinations or declinations will not interfere with the successful functioning of the circuit breakers and protective gear. Constructional details require to be of very robust character so that they will withstand a considerable amount of rough usage without being damaged. This particularly applies to such important units as the earth leakage protective gear and many colliery electrical engineers have confessed that earth leakage relays and instruments as fitted to many gate end boxes are either very difficult to maintain in good condition or they are left out of commission entirely. As this device is installed with a view to protecting the man on the face from electric shocks, etc., it is most essential that this above everything else should be reliable and dependable.

Having now described the contents of the portable sub-station, its application can be dealt with. Assuming that there is a double face with a centre gate at the end of which is the gate end loader with a conveyor on the face to the left hand and a conveyor on the face to the right hand, these being used for filling off the coal after it has been cut by machines or hewed by hand. In the event of coal cutters being employed, there may possibly be one coal cutter which will cut straight across the face including the heading, so that for this arrangement there are four electric motors which require to be connected to the source of supply. The motor for the gate end loader is, of course, mounted on the loader right at the gate end, and usually the motors for the conveyors on the face are placed on the face as near to the discharging point of the conveyors as is practicable. These three machines being of a semi-portable nature, that is to say they are only portable from the point of view of changing over the plant in the ordinary course of the advancement of the face, it has been found to be a practicable proposition to use pliable armoured cables for connecting the motors to the gate end switchgear. These cables can be permanently attached to the portable sub-station by means of suitable cable glands, and if plugs and sockets are fitted to the loader and conveyor motors, five-core cables can be used and the advantages of the low voltage earth circulating current retained. This should entirely dispense with the services of an electrician for disconnecting and reconnecting when changing-over.

For the control of the loader and two face conveyors there can be attached to the portable sub-station an additional cable, the loose end of which would be connected to a set of control switches which, in turn, could be mounted at the discharge end of the loader

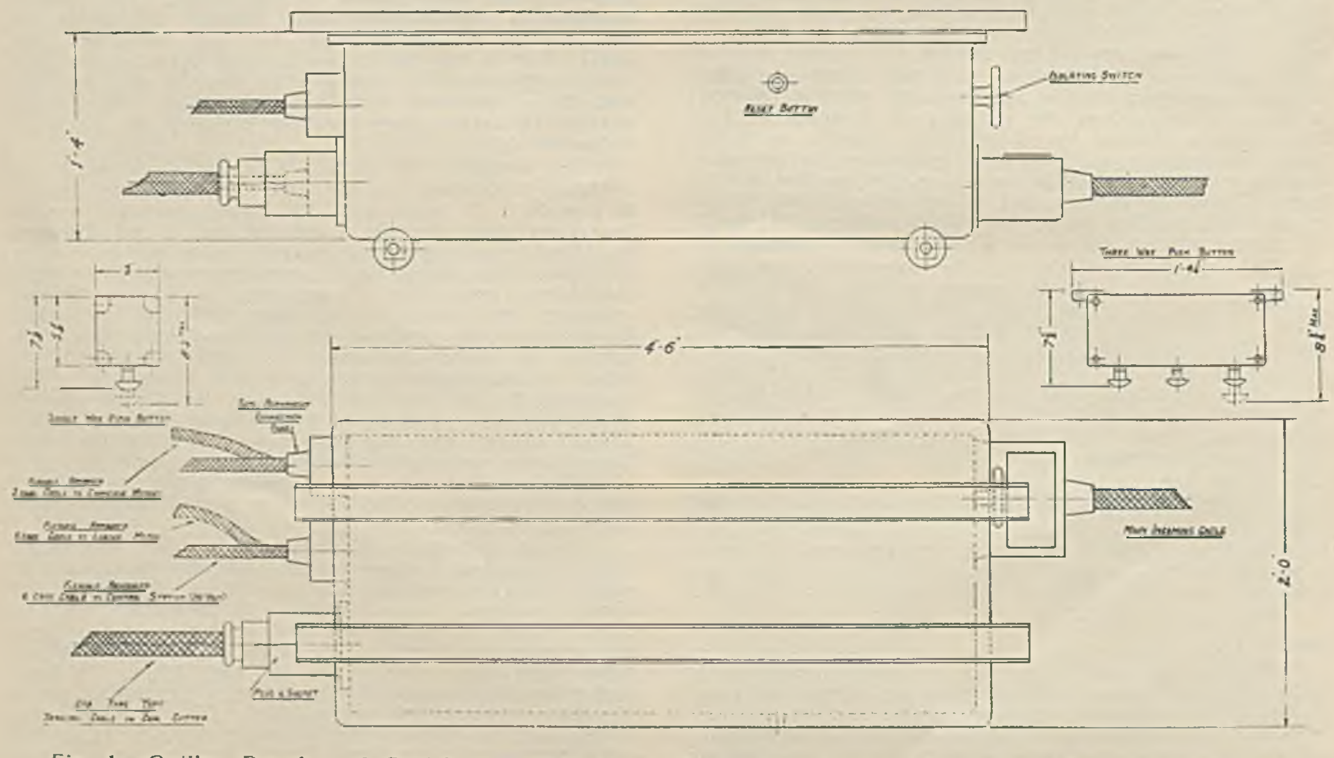


Fig. 1.—Outline Drawing of Portable Sub-Station suitable for One Loader Motor, Two Conveyor Motors and One Coal Cutter Motor.

and so give the man who is in charge of the filling of the tubs complete control over the loader and the two face conveyors. Such an arrangement prevents any operation of the circuit breakers for these machines unless the plugs are properly connected and the earth circuit is maintained, and the set of control switches is the only point that the man in charge has to deal with for the purpose of starting, stopping, and resetting after an overload trip or failure of supply.

With regard to the coal cutter, the conditions which prevail are somewhat different to the conveyor conditions. As the coal cutter propels itself along it is essential to have a more flexible cable with the possibility of it becoming damaged much sooner than the conveyor cables, so it is suggested that for the coal cutter the ordinary five-core cab tyre sheathed cable be retained with a plug and socket at each end so that it can be readily replaced in the event of any damage. This arrangement requires complete earth circuit continuity for the operation of the circuit breaker which connects the coal cutter motor to the supply, and with this arrangement complete control of the circuit breaker for the purpose of starting and stopping and resetting after an overload trip or failure of supply is obtained by means of a low voltage control switch fixed on the coal cutter.

The driver of the coal cutter and the man in charge of the conveyors need not under any circumstances concern themselves about the gate end switchgear except in the case of an earth leakage, in which case the whole of the motors taking supply from the portable sub-station would be automatically tripped off and the tripping mechanism held off so that no resetting could be done until the earth leakage device incorporated with the portable switchgear has been reset. This resetting could be left to the deputy in charge of the face or, if desired, could be so arranged that the services of an electrician would be required.

The latter, however, does not appeal to the mining man as it impedes production, and it has often been expressed that they would prefer to sort out the earth leakage themselves unless it was recurring, when they admit it is desirable to send for an electrician to deal with the matter. As, for instance, should the trailing cable to the coal cutter become damaged and an earth leakage created, the machine man has a spare cable handy so that there is not much object in sending for an electrician to detach a damaged trailing cable and replace it with an undamaged one, but at the same time the trailing cable having become damaged the earth leakage device would have operated so that it is rather a fine point as to whether the act of resetting the earth leakage device should be restricted to the electrician or otherwise.

The operation of the control switch is worth a little consideration: in this the points to be discussed are restricted to two movements, the rotating switch and the push-and-pull switch. With the former it is necessary for a handle to be grasped and the turning movement made in order to operate the switch. With the latter a switch could be designed which requires a deliberate and steady movement for switching on, but for switching off purposes simply requires pushing in, in a similar manner as, say, an organ stop. The author considers the push-pull switch offers advantages, particularly for emergency purposes, as it is the simplest thing in the world to push a knob with the palm of the hand, or even with the foot, should such a move be necessary in order to put the switch in the "off" position.

It will readily be seen from this, assuming the coal cutter driver notices that something has suddenly

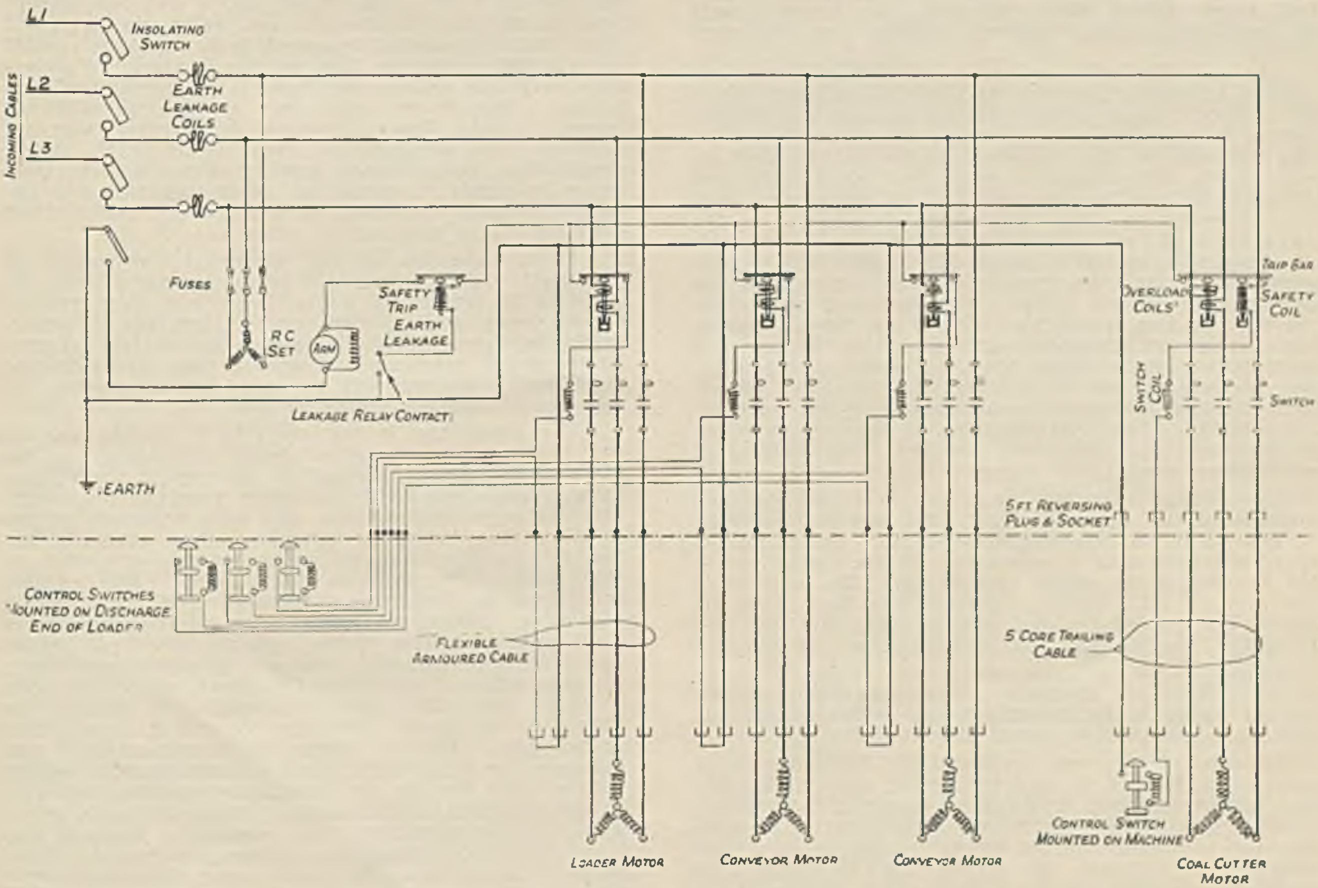


Fig. 2.—Diagram of Connections for One Loader Motor, Two Conveyor Motors and One Coal Cutter Motor. The apparatus and connections shown above the horizontal broken line are within the case of the "portable sub-station."

gone amiss, that instead of him feeling for and gripping a handle to switch off, he simply gives the control switch knob a push and the circuit breaker immediately opens. This, of course, is one of the main claims for remote control gear that everything connected to the main supply is switched off at the gate end except the low voltage operating circuit, this being necessary for the control switch which operates the main circuit breaker.

The low voltage local earth circulating current has been previously mentioned. This matter should be dealt with a little more fully in regard to the merits of a static transformer giving a low voltage alternating current, or a rotary transformer giving a low voltage direct current. As solenoid operated circuit breakers are to be used the type of current is one for serious consideration.

Assuming a static transformer to be employed, the circuit breakers need operating magnets with coils connected to a low voltage A.C. supply, and as the voltage must not exceed 25 volts it is impossible to connect the circuit breaker magnet coil direct to the pilot circuit owing to the very high operating current required, and so in its very simplest form the introduction of a relay, the coil of which is connected in the pilot circuit and the contacts of the relay used to make and break the main circuit breaker coil circuit which is connected across two phases of the incoming supply. With this arrangement, even when using a relay of reasonable design on 25 volts, the coil will require 8/10 amps. for magnetising current, so that there is a substantial number of watts to deal with in the pilot circuit and there is also the disadvantage of an inefficient main circuit breaker magnet with its inherent chattering and heating. Then again, this means operating magnets which are very susceptible and very much inclined to be erratic should slight variations in the supply voltage occur; a very important point indeed when the coal face becomes well advanced and cable resistance becomes an important factor.

As an alternative to static transformers and low voltage alternating currents the rotary transformer which is, in effect, a small motor generator set, can be used, the generator supplying a low voltage direct current. The idea of using a rotary occurred to the author when he was giving this subject a good deal of thought and although he has been accused of taking a very bold step, it seems to offer tremendous advantages. In the employment of low voltage direct current for the magnets of the circuit breakers, intermediate relays can be dispensed with, and as regards current consumption for operating the circuit breakers this has been reduced to one-third of that required on alternating current systems when relays are employed, and the circuit breaker coil currents can be reduced to a still much lower value for retaining the circuit breakers after they have closed. This reduced the power consumption of the solenoids considerably. This current reduction may or may not be of much value, but there are two other features of outstanding merit, these being:—

1. Voltage variation does not affect the operating magnets of the circuit breakers; the rotary transformer is dependent on the frequency of the circuit for its speed which, in turn, is responsible for the voltage across the brushes at the direct current end. The only effect the primary A.C. voltage variation may have is to increase the current on the primary side, but this can be easily provided for by using a rotary of sufficient capacity.

2. With D.C. magnets one has available definite current values in the operating coils which can be employed to give various novel characteristics.

In the arrangement developed by the author three amperes at 25 volts is used for closing a circuit breaker, and by the insertion in the pilot circuit of a resistance which is built in the control switch this current of three amperes is reduced to one ampere, which is more than sufficient to energise the magnet for the purpose of keeping the circuit breaker closed. This permits of the use of a safety trip relay, so that should the pilot core become in contact with the earth core in any part of its length between the circuit breaker and the control switch which (for this illustration, we will assume is mounted on the coal cutter) the safety trip would operate and open the circuit breaker owing to the current having been built up and sustained at three amperes.

These are two of the chief points and when coupled with the fact that no relays are required, no laminated magnets or high voltage coils, there is no heating of operating magnets together with the reduction in the space occupied by the gear, there is much more in the use of a rotary transformer than may appear at first sight.

Another important detail which the author has been investigating is the earth leakage protective gear. The usual device is a three-phase core-balanced transformer having the coils of three phases wound on a common iron circuit provided with a secondary winding which has a very small volt-ampere capacity should there be any flux in the transformer iron due to an out of balance condition set up by earth leakage, the transformer secondary winding being used to operate a relay of very frail construction.

It occurred to the author that as there is no flux in the transformer iron circuit when the phases are insulated, why not look into the possibility of making the transformer iron the relay magnet and use an iron circuit with a movable armature to which contacts could be fitted for the purpose of tripping the circuit breakers. Having got to this line of thought he devised what is really a combination of transformer and relay, and instead of using an induced current of a secondary winding to operate a lightly constructed relay, he employed the flux direct to attract an armature and so complete the iron circuit when an out of balance occurs due to earth leakage. The results obtained were quite astonishing, as with a very crude device and a very few ampere turns a combined transformer and relay was obtained which could be adjusted to operate with a leakage current of a definite value as low as one ampere. Furthermore, with this arrangement there is no question of percentage values to be taken into account, as whatever current may be flowing through the primary winding, whether it is supplying a 5 H.P. or 50 H.P. motor, should there be a leakage current of one ampere from the main supply to earth, the device operates and immediately opens the circuit breakers which are held off until the device is reset.

As an indication of the substantial construction of this earth leakage device it is to be noted that the armature is hinged on a ¼in. brass pin, this type of bearing being preferable to jewelled bearings. Furthermore, the operation of the leakage device is unaffected by reasonable gradients and uneven floor conditions, so that there is no necessity to worry about whether the apparatus is truly mounted or not.

The proposition is that on a fully machine worked face the portable sub-station should be installed in advance of the empty tubs and as close up to the ripping lip as possible, placing the apparatus alongside the loader. This, by some mining men, has been regarded as not an altogether convenient situation; they generally say that this space is required for the storing of timber or other material necessary in the working. The portable sub-station as devised by the author is kept within reasonable dimensions and, in one arrangement as developed, the whole of the apparatus required for the control of four motors is enclosed in a flameproof case, the dimensions of which are 4 ft. 6 ins. long × 2 ft. wide × 16 ins. high; the case is of sufficient strength for timber to be stored upon the top of it should that be necessary. This, of course, is not recommended and generally speaking, with a little co-operation, the mining people could provide the little accommodation required. In the foregoing dimensions a height of 16 ins. is given. This is rather important if the ripping at the gate end is restricted to a minimum, as the low height of the portable sub-station would enable a man either to straddle the apparatus or creep over it in order to get on to the face. This is, of course, assuming that insets have have not been made for the accommodation of the apparatus, the making of insets being a point which it is desirable to avoid.

To enable the main supply cable to be laid in straight lengths permanently in the road and do away with the necessity of looping the main armoured cable on itself in order to permit of extension with the advancement of the face, it is proposed that the main cable should be laid straight at the outset right up to the loader, where a straight-through joint box would be fitted at the end, taking from the joint box a length of about 50 yards of pliable armoured cable, which could be looped back or coiled as desired, to the portable sub-station incoming gland. The pliable cable would be uncoiled and extended up to its limit, after which an extension of the main supply cable would be made and the pliable armoured cable moved forward. This method should overcome the possibility of damaging the main supply cable with too much handling and avert the very common danger of "bird-caging" the armouring, which often occurs should a prop be accidentally set within a loop of the main cable.

The pliable armoured cable with this arrangement would be used over and over again at the gate end and when it shews signs of deterioration could be replaced with a new length.

It is not intended that the portable sub-station shall be restricted to the control of coalcutters and gate end loaders, as it can easily be arranged to include additional circuit breakers with overload protective devices for the protection of circuits to transformers as used with coal drilling machines and coal face lighting equipment. From this it will be seen that it is possible to incorporate in the portable sub-station any reasonable number of circuit breakers which can be arranged to protect any small accessories used on the coal face, thus providing for these accessories reasonable and substantial protective gear and at the same time avoiding the use of loose apparatus.

In considering the question generally of a portable sub-station, the following points appear to be of paramount importance:—

1. Full control of the gate end loader and face conveyors is desirable by means of control switches at the discharge end of the gate end loader, the switches usually provided with the conveyors could be retained for emergency stopping if desired by the man at the face.

2. For the coal cutter, full control by means of low voltage control switches mounted on the machines is desirable, so that it is unnecessary for the driver to leave the coal cutter for the purpose of resetting the gate end switch after an overload or failure of supply.

3. The portable sub-station being a self-contained unit there is no loose apparatus to be handled when advancing the face, or when it is necessary to move the plant at the gate end back for the purpose of, say, blowing down a heading.

4. The core-balanced earth leakage protective device should be capable of being adjusted at a much lower value than devices used with the distribution switchgear controlling the main supply to the portable substation

5. The apparatus employed ought not to be liable to erratic operation should there be a variation of supply voltage or more particularly subject to a variation of supply voltage due to motors of fairly heavy H.P. being switched direct to the supply. Solenoid controlled switches should be free from magnet heating and contact chattering, as these two points have considerable effect upon the apparatus from maintenance point of view.

6. The apparatus contained in the portable substation would require to be unaffected by reasonable gradients and uneven floors.

7. The method of making the connections between the portable sub-station and the motors should be such that the current cannot be applied until after the main main connections have been properly made. Furthermore, any attempt at disconnecting the motor whilst running should automatically open the circuit breaker protecting that particular motor.

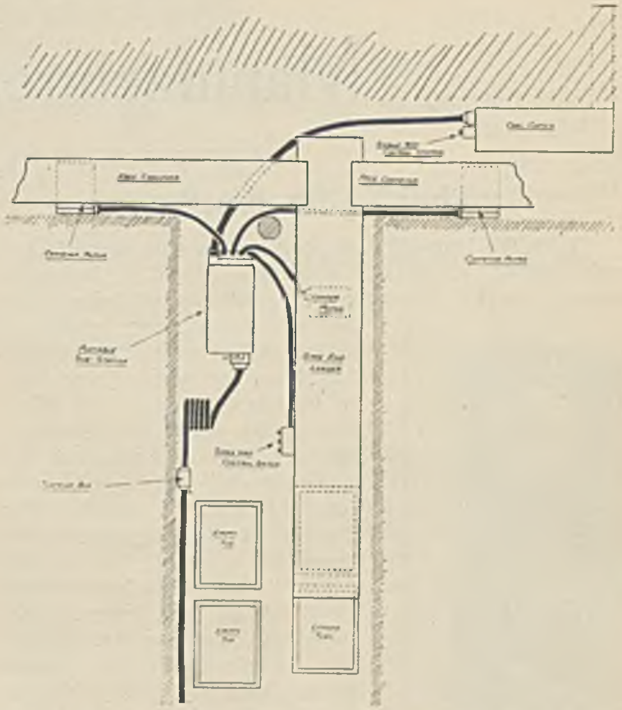


Fig. 3.—Plan showing position and general arrangement of a Portable Sub-Station below ground.

8. The protection of trailing cables is of importance and it should be desirable that the equipment switches off in the event of:—

(*a*) The pilot core becoming in contact with the earth core in any part of its length between the gate end switch and the pilot control switch.

(*b*) A main core becoming in contact with the pilot core.

(*c*) A main core becoming in contact with the earth core.

(*d*) A short circuit between phase.

9. The general scheme of control should enable the services of an electrician to be dispensed with when the plant is being moved about for ordinary mining operations.

In conclusion it is to be noted that this paper refers only to alternating current supply systems. This has purposely been done so as to avoid any possible confusion between alternating and direct current systems. It is, however, necessary to state that the whole control scheme here described is in every respect equally applicable to direct current systems and gives exactly the same degree of protection as is outlined herein for alternating current systems.

MIDLAND BRANCH.

The monthly meeting of the Midland Branch was held at the University College, Nottingham, on Saturday, December 22nd, 1928, Mr. R. Wilson presiding.

The following were elected to membership of the Branch: Member—Mr. Reginald E. S. W. Edwards, chief mechanical and electrical engineer, New Hucknall Colliery; Student—Mr. Arthur W. R. Baker, apprentice electrician.

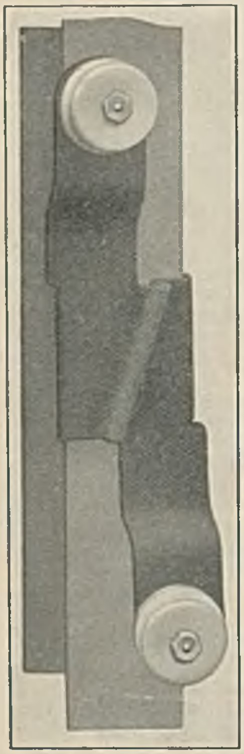
Mr. G. W. Grice gave an outline of a paper he was preparing entitled "Heating Troubles," and which he would read in an amplified form at the meeting to be held on April 30th next.

It was decided to hold the next meeting at Mansfield on Saturday, January 26th, 1929, when Mr. W. Wyness would open a discussion on the Report of H.M. Electrical Inspector of Mines for 1927.

Manufacturers' Specialities.

"Thor" Clip Brackets.

With the innovation of steel arches and supports for underground roadways, which is rapidly becoming general practice, there arose the difficulty of fixing cable and wire suspensions, insulators, pipes, etc. Haslam & Stretton, Ltd., have, fortunately, been able to introduce a simple and effective device which is even handier for these services than the spike or nail formerly driven into the wall or wood. The illustration here given clearly shows the simplicity of the "Thor" Clip Brackets. Plate steel strips are formed into pairs, each bent on the straight edge to take hold of the flange of the H-section arch and also bent on the slant at the other edge so as to form, with its complement, a binding wedge-grip. These clips are fixed immediately by merely placing them in position, perhaps a hammer tap only being necessary to ensure a secure hold. They can be released and removed with equal facility. A range of patterns and sizes to suit the particular gear which is to be suspended and standard section arches is available from stock; though, as will be readily appreciated, special forms or groups for multiple services can be cheaply and simply provided as may be required



Colliery and Industrial Lighting Cables and Fittings.

Those interested in the lighting and electrical equipment of collieries will find the Section B.E. of Henley's Catalogue—Colliery and Industrial Lighting Cables and Fittings—very useful. There is a wealth of matter pertaining to cables, boxes and fittings for installation in various situations and types of mine. All the equipment listed conforms to the General Regulations as to the installation and use of electricity in coal mines.

One of the specialities featured are cables insulated with "Herculene," the tough, non-hygroscopic insulating material, which is exceptionally resistent to physical and chemical action, thus being eminently suitable for shaft and in-bye mains in collieries. "Herculene" insulated cables have been supplied to many of the leading colliery companies in England, with most successful results.

Another speciality referred to in the book mentioned is the Henley Patent Electric Vulcaniser, which is a highly efficient appliance ensuring that the whole process of vulcanising is effected in a safe, simple and secure manner.

Henley manufactures include all kinds of electric cable for colliery use, insulated with paper, vulcanised bitumen, or the special "Herculene" insulating material; special types of cable to suit customers' particular requirements are also a distinctive feature of the Henley concern.

Six-Hundred Ton Haulages.

Vickers-Armstrongs, Ltd., have received an order for three sets of endless rope haulage gears arranged for driving by electric motors. The fleeting wheels are fitted with renewable cast steel treads and are driven by combined worm and spur reduction gears. The capacity of each haulage is 600 tons at 75ft. per minute. The three equipments as ordered are to be complete with tension terminals, haulage carriages and enclosed runway for the same, together with the steel haulage ropes.

NEW BOOKS.

H.M. STATIONERY OFFICE.

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

BOARD FOR MINING EXAMINATIONS.—Examinations for Certificates of Competency, First and Second Class, and Surveyors' Certificates. 21st and 22nd November, 1928. Price 1s. 9d. nett.

MINES DEPARTMENT.—Report on an Investigation at the Mines Department Testing Station, Sheffield, of the Safety of Certified Mine Signalling Bells when Connected in Parallel: by Capt. C. B. Platt, M.B.E., Superintending Testing Officer, and R. A. Bailey, Ph.D., Investigator. Price 6d. nett.

MINES DEPARTMENT.—Circular No. 31, 12th November, 1928. Electricity in Mines: Coal Cutting Machinery. To Owners, Agents and Managers of Mines in which Electricity is used. H. Walker, H.M. Chief Inspector of Mines.

HOME OFFICE.—Order No. 876, 1928. Dangerous Occurrences Notification, revoking the Order dated 22nd December, 1906, and coming into operation 1st January, 1929. Price 1d. nett.

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