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Science Sets the Pace.

If we were asked to sum up the general opinions heard and seen expressed as to the prospects of the New Year we would at once have to mention that prominent amongst the impressions marked is a new and serious trend of thought. People today seem to be wondering whether the world is moving too rapidly; whether the irresistible man-made machine has not begun to overpower man. Scientific discoveries have outstripped even the breakneck pace of international competition. Artificial silk, road transport, mineral oil—these are some of the scientific discoveries which with explosive force and speed have virtually shattered great industries. Staple industries are being driven to the wholesale scrapping of plants and works and sites. Transport and means of communication and other inventions have made this country as merely a city and its agriculture as but a rural market garden: the oceans are but as channel crossings.

The constant in these changing values is the unit of man. He is tossed, individually, hither and thither in the whirl and turmoil of hugely overgrown companies, combines, trusts and syndicates. He endeavours to mould mankind to suit, and would sink his harassed self into great mass-movements. He has tried nationalisation, trades unionism, social communism, co-operative societies. He is seen still persisting in these efforts to weld dissimilar vital units into a coherent force wherewith to hold, stem, and control the formidable giants bred from scientific progress.

It would appear as if the distressful effects of the protracted world depression have at last driven home many unpleasant truths and men are thinking hard. The world today is asking, and not without some bitterness, whether there is anything good to be expected from this standardised age of compacts, agreements, combines and corporations. There has grown that tremendous feeling of doubt in the minds of men: and great as is that question how much more formidable and ominous is the succeeding enquiry—who or what will stem the tide which threatens civilisation?

Serious as is the public mind in this general apprehension regarding the drift of events, there is happily no noticeable tendency to shirk the issue as being one without hope. The past few months have as ever shewn that with the revelation of impending danger we, as a nation, are quick to perceive and utilise the means of defence.

May we not then, having these broad principles before us, turn to look again at one or two definite recent events. The contracts for completing the greatest airship and the greatest ocean liner have been suspended indefinitely. On the grounds of economy Britain is not to proceed with these "greatest-wonders." We do not know whether it is that the economic consideration is based upon the estimated inability of these vessels ever to earn an adequate return on their capital cost, or whether it has become evident that such vessels are obsolete before they are built: the point is that they are both hugh conceptions of scientific progress.

Let us come a little nearer home and introduce an electrical example—National Electrification. Frequency is standardised and the "grid" straddles the face of the country. An enormous amount of money has flowed into this scheme. For years the greatest experts of science and engineering considered and planned and then put their decisions into effect. Alternating current, fifty periods was agreed as the best for the all-round national electrical system. It will interest readers to turn back to the address given by Mr. Frank Anslow on the occasion of his installation as President of the Association of Mining Electrical Engineers, published in our issue of July 1928. Commenting on the selection of system for national electrical supply Mr. Anslow warningly stated that standardisation should be effected at the very least expense, he indicated that there was a risk of planting a millstone round the neck of a future generation: electricity "may produce developments revolutionising entirely and in many directions present methods." In so many words he asked "What for instance would be the effect of the successful development of a high tension direct current system of transmission?

Last month our esteemed contemporary *The Electrical Times* published an article describing in detail the remarkable high power results which a Swiss firm has gained in developing the usage of mercury arc rectifiers with grid control. The editor of that journal seeing the potentialities of this great practical advance in the industrial application of well known scientific principles, is prompted also to question what the next ten years will hold in store. The new discovery makes practicable and easy, by inverted operation of the mercury arc rectifier, the production of high tension direct current—the ideal form for distance power transmission. The valve control takes the place of commutation for direct current and single-phase motors. Single-phase, variable-speed motors, reversible, regenerative and more economical are available. A locomotive is being equipped, for service on the Swiss railways, with two 500 horse-power, single-phase, non-commutator motors on this system. Rotary converter machinery becomes obsolete: frequency change is a simple affair by means of a static appliance.

Verily these are strange times. We must be progressive, right in the van of progress—but how to keep pace with the drive of scientific achievement is the greatest present concern and difficulty of the individual as it is of earth's nations.

A.M.E.E. Council Meeting and the British Industries Fair.

Members of the Council of the Association of Mining Electrical Engineers are reminded that the next meeting will be held at the Queen's Hotel, Birmingham, on Saturday, 27th February. The date and place of the meeting were arranged to give members the opportunity of visiting the British Industries Fair, and it is gratifying to note that the management of the Fair have very kindly invited the members to luncheon at the Fair at one o'clock on Friday the 26th, and subsequently to spend the afternoon in making an official tour of the sections where mining electrical work is in particular prominence. In consequence of the difficulty of obtaining hotel accomodation in or near Birmingham during the Fair, it is advisable that those who would wish to stay overnight should book rooms at once.

The "MG7" Aluminium Alloy.

A new light metal alloy of aluminium with magnesium and manganese is the subject of a patent by James Booth & Co. Ltd. At present named "MG7" the new metal is very similar in its general mechanical properties to Duralumin. In rolled form it is stronger than rolled and heat-treated Duralumin; in bar and forging it is not so strong; in tubes it is of equal strength. It is not amenable to heat treatment and variations in strength can only be made by cold working. Though cold working and shaping hardens the metal it is of high initial strength and, consequently, with intermittent re-annealing it can be worked satisfactorily to suit requirements. The principal physical characteristics of "MG7" are: Specific Gravity, 2.63; Annealing Temperature, 380 deg. C.; Forging Temperature, 400/420 deg. C.; Brinell Hardness, 90/115; Izod Impact Value, 17 foot lbs.

The metal is highly resistive against corrosion, particularly atmospheric and sea water. It can be produced in all standard wrought forms such as sheet, tubes, strips, rods, extruded sections, rolled and drawn sections, wire, rivets, bars, forgings, and drop forgings. It is therefore suitable for complete constructions, even to the jointing pieces, and free from any trouble due to galvanic action.

British Standards for Collieries.

The British Standards Institution has issued a formal report concerning the work done in the past year and the particular subjects it is now engaged with. This work was undertaken at the request of the Mining Association of Great Britain in 1923. Some twenty-two specifications have been issued and it is a clear indication that the mining industry as a whole fully recognises the value of the work to note that 20,000 copies of the specifications have been sold since 1926.

Amongst the British Standard Specifications which have been issued during the past year, the following are of particular interest to colliery engineers: Steel Tub Wheels and Axles; Shaker Conveyor Troughing; Sampling and Analysis of Coal for Inland Purposes; Compressed Air Receivers; Riveted Air Receivers; Forged Air Receivers; Solid Drawn Air Receivers; Test Sieves.

Subjects being dealt with at the present time include: Land Boilers; Pump Tests; Rubber Conveyor Belting; Fibre Cores for Wire Ropes; Capping Metal for Wire Ropes; Engineers' Files; Trailing Cables; Cable Glands and Sealing Boxes.

The Institution takes the opportunity of reminding readers that it is not a profit-making concern and, apart from grants received from H.M. Government, and the amount derived from the sale of its publications, it has to look to British industry for the funds necessary to carry on the work.

Every British firm and every individual engineer is eligible to become a member of the Institution at a nominal fee. Membership carries with it certain valuable privileges and advantages, and it is hoped that all manufacturers and others in the mining and electrical industries will co-operate in this work by becoming subscribing members.

The Melchett Medal.

The Institute of Fuel announces that the Melchett Medal for the year 1931 (the second to be awarded) will be presented to Prof. William A. Bone, F.R.S., of the Imperial College of Science and Technology, South Kensington, by the President of the Institute, Sir Hugo Hirst, Bart., at the Institution of Electrical Engineers, London, on February 1st, 1932.

The Melchett Medal was instituted by the Founder-President, The First Baron Melchett of Landford, who presented to the Institute a sum of money sufficient to found the Medal in perpetuity.

The Melchett Medal is awarded annually to such person, whether a member of the Institute or otherwise, as in the opinion of the Council has done either original research or professional, administrative or constructive work of an outstanding character, involving the scientific preparation or use of fuel, provided the results of such work have been made available within recent date for the benefit of the community. The award is made without restriction as to the nationality of the recipient.

Following the presentation, Professor Bone will deliver the Melchett Lecture, his subject being "A Century of Fuel Economy."

Calendars and Diaries.

We have to acknowledge with thanks the seasonal greetings received along with many Calendars, Diaries and other useful and artistic acticles. Particular mention in this respect may be given to: "Lionweld" Steel Flooring & Stairway Co.; Macintosh Cable Co. Ltd.; Haslam & Stretton Ltd.; British Insulated Cables Ltd.; Liverpool Electric Cable Co. Ltd.; Hart Accumulator Co. Ltd.; C. A. Parsons & Co. Ltd.; Enfield Cable Works Ltd.; Cosmos Lamps; United Steel Cos. Ltd; Geo. S. Ikin & Son, Ltd.; Exide Batteries; General Electric Co. Ltd.; John G. Stein & Co. Ltd.

Proceedings of the Association of Mining Electrical Engineers.

MIDLAND BRANCH.

The monthly meeting of the Midland Branch was held in Mansfield, on Saturday, November 28th, 1931, Mr. C. D. Wilkinson presiding. After the minutes of previous meeting had been read and passed, the following were elected to membership: (Associate) Mr. Geo. H. Winwood, 17 Beauvale, Newthorpe, Colliery Electrician; (Member) Mr. John Percival Davey, 271 Oak Avenue, Garden Village, Stocksbridge, Sheffield, Chief Electrician.

It was arranged to hold the next meeting on Saturday, January 2nd, 1932, at the Albert Hotel, Nottingham.

Mr. C. D. Wilkinson, having been re-elected President of the Branch, then gave his second Presidential Address as follows.

Presidential Address.

Technical Training and Examinations.

C. D. WILKINSON.

These notes touch briefly on some aspects of the technical training of electrical engineers, indicating some of the difficulties and a method of overcoming them. The majority of electrical engineers obtain their technical training in evening classes, since stern necessity usually prevents them from taking a full time day course at one of the Universities or Technical Institutions.

To study for any of the higher examinations by such evening classes involves attendances for at least three evenings a week, for four or five years. Such a course of study makes a great demand on a student. Anyone who has done a hard day's work in the pit or shop is not in condition to benefit fully from the tuition given. The student is more or less physically exhausted and the greatest demand on his mental energy is made at the time when he is least able to meet it. Fortunately there is no lack of pluck and determination, and as a rule, the question of ambition is involved.

An evening student sees the possibility of obtaining by study and mental effort, a recognised professional qualification which will enable him to improve his status and overcome his initial financial handicaps. He therefore enters on his course, realising that he will be much longer in gaining the desired qualification than he would be if taking a day course.

Even with a five years' course the actual time devoted to organised study is much less than that of the more fortunate day course student, so that a qualification earned by an evening student carries with it an additional guarantee of pertinacity. The standard set in evening institutions is high, with the result that that only a small percentage of the students admitted go far enough to take the higher final examinations. It may be thought that better results could be obtained if the ground were not covered so swiftly. The subjects included in a syllabus to be covered in a normal session appear formidable, and in view of the fact that the examination may include anything in that syllabus, greatly accelerate the rate of teaching. This might seem a disadvantage, and it does undoubtedly weigh heavily on the less brilliant student, but the keen student supplements his class work by study at home, so that in his case, the work is well covered.

Courses are usually of a general rather than a specialised character, but this is purely a matter of demand. If a sufficient demand for a special subject exists it can be met, but one finds little demand for vocational training. Colliery electrical apprentices seem to prefer a National Certificate Course to a Mining Electrical Course, and this may be indicative of a desire ultimately to cut themselves adrift from colliery work.

This tendency, together with the undoubted migration which is taking place from the colliery electrical staffs, makes one apprehensive as to the supply of good colliery electricians for the future. The drain will continue so long as it is possible to obtain better remuneration as an unskilled colliery worker than as a responsible craftsman.

This is by the way and, returning to the question of special classes, it must be remembered that most technical institutions are dependent on grants from the Board of Education. This body can specify the minimum numbers for the different grades, and if a class falls below the minimum it must close. The minimum is lower for the more advanced classes, but in scattered areas it becomes difficult to maintain all classes in a grouped course, although the Board always gives these points the most sympathetic consideration.

A grouped course is the one the student should take because the general education in engineering, cannot be neglected without serious risk. Only the best students make progress in all subjects of a group course, and when one considers that such a course involves travelling and attendance for three evenings a week and also homework one must realise that there is little time for recreation. The strain begins to tell towards the end of the session, and attendance and homework begin to fall off. The student is tempted to cut all but the central subject in his course, and does not realise until too late that the subjects in the course are definitely correlated.

A percentage of students fall out at the end of each session, some eliminated by the terminal examinations, and others through their inability to tackle the increasingly difficult work. This loss is relatively high in the case of electrical engineering since this subject makes higher demands on both the intelligence and imagination, than any other subject. Senior classes are therefore small in number and one is tempted to ask whether the system does not bear too heavily on the less brilliant student.

On reflection the opinion is formed that any lowering of the standard of examination or slowing down of the course is undesirable. The students who fall out before completing the full course have acquired some technical training and are therefore likely to make better craftsmen. Their inclinations may lean towards practical work rather than technical attainments, and one must remember that the skilled craftsman has a most important part to play in industry.

The students who do get through have the advantage of knowing that if the standard of examination is high, the qualifications earned have a correspondingly definite high value and are worth the struggle.

Examinations should not be the only aim of technical education. What should be aimed at is the imparting of a sound knowledge of principles and, what is equally important, a knowledge of how to apply those principles to overcome practical difficulties. Training on these lines is more useful than the "cramming" of formulæ. The accusation that a theoretical man is of no use in the face of practical difficulties has no solid foundation. This accusation should be levelled at the man who cannot apply his knowledge, and such a man cannot be said to possess a theoretical knowledge.

All the foregoing prompts the thought, "Is the present system, in which such a small proportion of enrolled students get through the higher examinations, the best available?"

The inherent disadvantages of evening education, which have been sketched here in outline, prevent an increase in the efficiency of the system. Some of the larger engineering firms appreciate the difficulties and have systems in operation in which apprentices are compelled to take part time day courses at technical institutions. Such firms deserve congratulation and it is to be hoped that an ever increasing number of industrial concerns will adopt similar schemes. The technical institutions are well equipped and can cope with day students, in fact they would all welcome such an influx. Whilst fully recognising the difficulties which confront employers in these depressed times, one hopes that any improvement in trade will be accompanied by an increase in the number of firms adopting the part time day course scheme.

Any reference to technical education would be incomplete without reference to the important part played by such Associations as this. The papers in *The Mining Electrical Engineer*, and the interchange of views at the monthly meetings are of great benefit in giving one a wider knowledge of electrical engineering. Another advantage of the meetings is that they provide a training ground for self-expression in public. The importance of this point cannot be over-rated, since self-confidence and an orderly expression of one's ideas, both most desirable assets, only come with practice.

Finally, the further the education of anyone progresses the more fully he realises the truth of what Sir Isaac Newton wrote shortly before his death, "I seem to have been only a small boy playing on the sea shore, and diverting myself in now and then finding a smoother pebble or a prettier shell than ordinary, whilst the great ocean of truth lay all undiscovered before."

Mr. G. P. GRICE, in proposing a vote of thanks, reminded members that there would be no discussion on the address, but he would like to thank Mr. Wilkinson for his able description of the various courses which were necessary before a student could obtain one of the higher certificates of efficiency. Mr. Wilkinson had shewn that he fully realised the difficulties that were encountered by students attending the courses, especially the working students who had to take their study in leisure time.

Mr. WYNESS said he had great pleasure in seconding the vote. He felt it was a great pity they were debarred from discussing the address, as it did offer great scope. It was a very well thought out paper.

Mr. Wilkinson then opened the discussion on the Association Sub-Committee's recommendations on Surface and Underground Lighting.

Surface and Underground Lighting.

Discussion.

Mr. C. D. WILKINSON.—The question of underground lighting is in such a state of flux that it would appear more desirable to call for comments and discussion rather than definite resolutions. Considering the queries raised by the Association sub-committee, the first concerns the new standard of candle power. In the draft regulations the new candle powers asked for are 1.3 C.P. for every new lamp, and 1.0 C.P. for every lamp. Our sub-committee ask that these figures be increased to 2.25 C.P. and 1.75 C.P. respectively. What is more important, they ask that these candle powers be mean spherical candle powers. In the case of a hand lamp the reduction factor is low, so that the increase asked for by the sub-committee is very large. It remains to be seen whether such increases can be obtained without undue increase in the weight of the lamp. The Branch of the Association proposed quite large increases in candle power, so that apparently the sub-committee and ourselves are in agreement.

The increased candle powers would, according to the draft regulations, have to be effected in approximately three years; in proposing the extension of that period to five years, our sub-committee indicates the necessity of easing the financial burden.

Mr. Wilkinson said he believed everyone agreed that a better light was necessary, and the two chief benefits to be derived were a reduction in the incidence of nystagmus and the prevention of accidents. With better light there was a better chance of seeing roof slips and other potential dangers, whilst anyone who had come in contact with nystagmus cases knew that this disease caused great personal suffering.

Regarding the weight of the lamp, Mr. Wilkinson held the opinion that this was not so important in the case of a face worker, but it was important for the haulage hand. Tests had been made with a larger lamp at some collieries and some miners who at first protested against a heavier lamp, asked after a week to be allowed to retain them.

The effect of better illumination was sure to result in increased output. This had been proved in engineering shops and industrial works, greater output having been secured and also less faulty workmanship. The same results were bound to obtain at collieries.

Turning to other means of direct lighting, the new proposals which permit the use of fixed lighting in any roadway (considered safe by the Inspector) up to 100 yards of the face was sure to be most beneficial. There were many busy and important junctions in return airways which could not be illuminated at present. Mr. Wilkinson could see no reason why lighting should not be installed, provided there was no gas and that suitable apparatus was used.

The members of the Association had been asked to state their views on a number of points regarding coal face lighting. The first of these was voltage and wattage of lamps and the distance apart. In the discussions which had already taken place, pressures as low as 12 volts had been recommended. That was too low because it would limit the application to very short faces: 25 volts should be the minimum, since that pressure whilst eliminating shock risk, extended the useful range. Twenty-five watt lamps about 8 or 10 yards apart should give good results, but the spacing would need to be tried out.

The only type of fitting suitable was the prismatic which had a stronger glass than any other. The majority of light was required on the face side, and also on the gob side where slips were likely to occur, so that the oval prismatic type was best. The cable entry would need re-designing so that the axis of the cable would be coincident with the major axis of the oval glass. The question of junction boxes involved both the type of cable fitting and entry to fitting.

A pliable armoured cable, C.T.S. either twin or concentric, was desirable. A concentric cable might prevent internal faults getting through to the exterior of the cable, but there is some uncertainty as to how it would stand up to the rough usage. The connectors and connections to the fittings should be of the plug type, with bayonet fittings which would ensure that the circuit was broken before the plug was withdrawn. These would have to be of alternate male and female pattern and care would have to be taken that the plug nearest the supply was female.

The transformer could be similar to those used for electric drilling, earthed at the mid-point and with D.P. protection. The low voltage would make it unnecessary to instal leakage gear.

The question of the frequency of the lighting supply also needed consideration. Some time ago Dr. Thornton carried out experiments which shewed that the interruption of quite a large current was necessary to ignite firedamp, at higher frequencies than normal. He also claimed that it needed 20 amperes at 200 volts to ignite firedamp if the supply frequency were 100 cycles. This led one to hope that lighting installations could be made quite safe, even in an inflammable mixture, since the safe currents would be more than sufficient for lighting circuits.

Unfortunately, the later experiments of Dr. Wheeler led to absolutely different conclusions. He found that the igniting current depended on (1) rapidity of break, (2) inductance of the circuit, (3) the area of contact at the time of the break, (4) the volatility of the metal in the spark gap, and (5) that the character of the supply whether a.c. or d.c. did not seriously affect the ignition.

These differences of opinion are hard to understand, and Mr. Wilkinson thought that a recommendation should go from the Association asking for further research to be undertaken in that direction, on experimental circuits which approximated as nearly as possible to ordinary mines lighting circuits.

The question which would make or break coal face lighting, was that of cost, and it was for the members to put forward recommendations which, while adequately providing for safety, would not be so severe as to prevent their adoption for financial reasons. Any rules framed must be stable, so that there would be no costly alterations once an installation was completed.

Mr. LEES said he was quite in agreement with Mr. Wilkinson in most of his ideas as regards the voltage and wattage of lamps and the type of fitting, but whether we could put forward that type of fitting was doubtful as, so far as he knew, it was only made by one manufacturer. As regards fittings, he thought a strong internally ribbed frosted glass would be all right.

He did not altogther agree with the method of control by fuses. There were suitable circuit breakers made for small current and at a cheap price, which he thought would give all that was required in that direction.

The question of high frequency was still a matter for debate. He thought that what was common practice in roadway lighting could be carried out further in-bye; with armoured cable, of course.

In regard to coal face lighting, it would be necessary to determine the length of face for the type of transformer to be used. He was quite in agreement with keeping down to 25 volts, 50 volts had killed a man and 25 volts had killed a horse; also with a low voltage they could get a stronger type of bulb which would stand more knocking about—similar to a motor car bulb.

He had made calculations as to the size of cable to be used.

1. For 100 yards of face and transformer 50 yards away up the gate, six 12 volt 36 watt lamps, 20 yards apart, the total voltage drop is 4.1 on a 0.0225 sq. in. cable.

2. Similar arrangement at 24 volts gives a voltage drop of 5.26 on a cable 0.01 sq. in.

3. 200 yards of face, transformer as foregoing, 11 lamps, 24 volts, 36 watts, gives a total voltage drop of 3.52 on a cable 0.0225 sq. in.

Probably 18 watt bulbs, 10 yards apart would be about right.

The examples shew the large size of cable required, 0.01 sq. in. would not be too large. the greater the size, the greater the mechanical strength to withstand the strain put on the cores.

If they went to 60 watt lamps on the coal face there would be complaint of glare, which might be got over by well-frosted glass.

Mr. Lees thought the controls might also include some form of leakage gear. Transformers might be three-phase to one-phase with the mid-voltage point brought out. He had not any experience with pliable armoured cable, but he certainly thought C.T.S. would be required.

Mr. GRICE said the collieries with which he was connected were using a number of alkaline battery hand lamps, and although the weight was fairly considerable, approximating 11¼ lbs. each, the men who used them were very satisfied. No one had yet asked to be relieved of his lamp on account of the weight; in fact their only fear seemed to be that they would be taken away and given to someone else. These lamps had a two cell 2.4 volt steel nickel cadmium battery, having an average voltage over the shift of 1.2 volts, and the C.P. was given as 4.

As regards the effect on nystagmus cases, Mr. Grice thought it was early yet to express an opinion. The percentage of accidents definitely due to insufficient lighting was estimated to be about 5%, and as accidents would not be entirely eliminated it was reasonable to assume that they would be reduced by improvements in lighting.

As to increased output and clean coal, Mr. Grice said there was no doubt that the output would be substantially increased, but he was afraid the coal would not be sent out much cleaner; he thought this was rather a problem for the screening plant, and if the lighting on the surface was improved the coal should naturally be better picked on the belts. The problem of lighting picking belts was in itself a difficult one. Coal absorbs a considerable amount of light, and as the appearance of certain grades of coal and jack is very similar it is difficult to pick them out on a moving belt which is usually of a similar colour.

Referring to fittings, Mr. Grice said they had tried a number of different well glasses and had, as a result, formed the opinion that the frosted prismatic was the most suitable. The 4 C.P. lamps mentioned were fitted with frosted prismatic reflectors: he believed that in the past the regulations had not permitted the fitting of these and was of opinion that a correctly designed reflector would be of benefit.

Regarding coal face lighting from power circuits he was in agreement with Mr. Wyness, and thought 75 to 100 volts could be used. The distance apart and wattage would have to be determined by experience. The type of fitting would have to be very robust, and would have to be very robust, and would have to withstand being dropped, dragged and generally maltreated.

Mr. WILKES.—Referring to the question of voltage mentioned by Mr. Wilkinson, said he understood that the Mines Department had had it under consideration and were prepared, in re-drafting the regulations, to allow anything from 6 volts to 110 volts. He thought that whatever was adopted there should be a recommendation not to allow a variation in voltage, but to stick to one standard voltage. It would eventually react to the benefit of colliery companies and cheapen the cost if manufacturers had one standard voltage to provide.

The only thing which occurred to Mr. Wilkes with regard to the high voltages from 60 volts to 110 volts, if they were going to consent to that, was that there would be the convenience of incorporating coal face lighting with electric drilling. All up and down the country they were hearing of electric drills taking the place of compressed air drills, and he had no doubt that as things were going British firms would awaken to the fact that these were required. He thought the two could be combined and drills and lighting taken from one transformer, preferably situated at the gate-end.

Mr. Wilkes said with regard to the type of plug suggested by Mr. Wilkinson, there was at least one on the market exactly similar to that described. Mr. Wilkes had, personally, found pliable armoured cables very effective; they were largely used in the North of England.

Mr. WYNESS said if coal face lighting came he was quite prepared to have it at 110 volts or 125 volts, and saw no reason why it should not be satisfactory. Regarding the method, he thought a three-phase transformer was quite suitable; it provided an extra circuit, there would be the tapping off of three wires and the incorporation of a pilot core in the lighting cable. With coal face drills there would have to be separate protection of the lighting circuit from the drilling circuit.

In considering the spacing of lights, it must be remembered that there would be no help from the surrounding surfaces, so that it would be necessary to have the lights rather closer together than would be required for normal conditions. The first impression one got was that coal face lighting was not possible today because there were so many regulations which were very drastic. It would certainly increase the cost of the electrical staff. A plug fitting was undoubtedly the only fitting that could be used on the coal face, as it would have to be put up in sections and taken down. He was of opinion that gate lighting should be made possible right up to the loading end, and that in most pits it would entail no danger.

Mr. F. SMITH asked, with regard to fuses and circuit breakers, if these tripped or were blown who would be the man to replace them? Did it mean that the electrician would have to go each time to find the cause? If a leakage trip came out only an authorised person was allowed to find out why it had tripped. With regard to electric lighting taken off the power supply, if the power failed there would be a cessation of work. His idea was that the lighting might best be taken off large accumulators, similar to motor car accumulators with three or four lamps off each.

The taking in and bringing out of these large accumulators might have to be done on afternoon or night shifts in the same way as timber. Such accumulators should be designed to stand the jolting of pit trams and capable of being taken up roads rising 1 in 3, and used on steep faces.

The adaptor cable, say one for every one or two lights should have the fuse built into the plug, so that a faulty cable or fitting would blow its own fuse and the spare cable could be put on to the battery by an unskilled man. The plug could be made flame-proof on the lines of the plug as used with radiators, that is, the plug should be inserted and given a right hand turn, thus interlocking it and making contact with the battery.

With regard to fittings, his idea was a rolled or pressed steel fitting, which would be quite light in weight to handle.

On the question of the cleaning of coal, Mr. Smith pointed out that some colliery screening plants had an all-glass roof; others were roofed with patches of glass and corrugated sheeting which, in dull weather, gave a mixed illumination of electric light and daylight, which was extremely unsatisfactory for coal screening and made it almost impossible to distinguish batts from coal.

Mr. KITCHEN said, on the point of voltage, he thought the situation would be best met by using the lower voltage and bringing out the centre point so as further to limit the danger of accidents.

Regarding fittings which one could plug together and remove, say, a defective portion, this operation was limited because it called for an electrician to locate and remove the faulty part and to test the whole before it could be again put into use; therefore to maintain a successful power-lighting outfit at the coal face would call for a larger electrical staff than was usually found at a colliery.

Mr. WRIGHT said he quite agreed that coal face lighting was a matter of conditions; he thought at most pits there was not sufficient lighting. With regard to hand lamps, he thought the weight of these was a great consideration.

Mr. Wright considered that the new standard of mean spherical candle power was an improvement on the old horizontal C.P.: with regard to the angle of light, the minimum illuminated area should be specified, and with regard to the min. C.P. of 1.75 it should be specified to be at after a certain number of hours of lighting. For effective illumination for the picking of coal on the screens, Mr. Wright recommended the use of the blue daylight lamp.

Mr. WM. SMITH.—With regard to coal face lighting, the miner has to carry the lamp down to the face, and any improvements ought to be in the hand lamp itself. He could not see where coal face lighting from a supply was going to be of any great advantage.

Mr. BARNES considered that better lights on the screens would enable the coal to be picked much cleaner.

Mr. WILKINSON, answering a question by Mr. F. Smith as to the capacity effect in a concentric cable with the small current taken by lamps, said that the short lengths used would ensure that the capacity as a whole would not be high. The dielectric would certainly have a high specific capacity, but there would be no chance of high pressure rise, as the two conductors would be shunted by the lamps. There would be no fear of resonance through either the fundamental or harmonics.

In conclusion, Mr. Wilkinson said his opinion of the discussion as a whole seemed that there was a fairly divided opinion between low voltages and 110 volts. Higher voltages had attractions, the smaller cables necessary meant reduction in cost, and that might go towards buying leakage gear. His own idea in leaning towards low voltages was that they might get a more simple system. Mr. Lees had stated that there was no reason why electro-magnetic overload releases should not be used instead of fuses; that again was merely a matter of cost. Mr. Smith had raised a searching question: Why have general lighting when a man must have his lamp to look under the face?

Taking into account costs and other things it was a question whether it was not an improvement in the head lamp itself which was going to gain the day rather than general lighting. All things considered he was of opinion that they had had a very satisfactory discussion on the points before them.

Mr. WILLIAMS, in proposing a vote of thanks to the Chairman, said he would like to congratulate him for the very able way in which he had handled the subject.

Mr. E. R. HUDSON seconded the vote, and the meeting then closed.

STOKE SUB-BRANCH.

Electric Winders.

B. A. JEFFERIES.

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

The object of this paper is to bring to the attention of the mining electrical engineer some of the things which he should consider before installing an electric winlder at his colliery. It is assumed that the colliery is not one of those rare cases where a steam winder is more economical than an electric winder; such pits undoubtedly exist but it is practically certain that, although there have been scores of instances where a steam winder has been superseded by an electric winder, there has never been an instance where an electric winder has been replaced by a steam winder. If the price of electrical energy tended to go up steam winders might become more popular because of lower running costs but the tendency is all the other way and so it would appear that winding engines of the future will all be electrically driven.

Another assumption is that the conditions are such that a Koepe pulley winder is not a practical scheme, i.e., a winder where the "drum" consists of a pulley with a single groove, the rope being taken from one cage over one head sheave, around most of the perimeter of the pulley, in the groove, and back over the other head sheave to the second cage: a single rope being used. The Koepe winders are fairly common on the Continent but are only possible when the conditions are favourable, i.e., a comparatively light load, and a deep shaft. A balance rope is essential with such a winder and a rapid rate of acceleration is not possible because beyond a certain rate of acceleration the rope will slip. Conditions at the majority of collieries do not favour such a type of winder.

Flat ropes are rarely made now, at least in this country, owing to the difficulty of maintaining the stitching so that we shall have to leave out of practical consideration the bobbin winder.

The colliery engineer is therefore left with the choice from the following types of winder:

1. A winder having a plain parallel drum keyed on the drum shaft.

2. A winder with two parallel drums one or both running loose on the shaft and having a clutch or clutches to connect it or them to the shaft, the clutch being usually of the multi-tooth type.

3. A cylindro-conical drum winder where there is a single fixed drum with a large diameter at the centre and two smaller diameter portions at the ends, these being connected to the large diameter part of the drum by cones on which spiral grooves take the rope from the smaller to the larger diameters.

4. A conical drum winder where the drum consists of two conical portions the larger diameter being usually at the middle and the smaller diameters at the ends. On this drum the rope is wound on in a continuous spiral groove on each side.

Number 3 has for the most part superseded Number 4 which need not here be considered.

In each case the drum would have a brake rim or brake rims (usually two brake rims per winder whether there are one or two drums) this forming part of the drum itself or being bolted to it by fitted bolts.

The drum shaft is driven by an electric motor either directly coupled to the shaft or through gearing.

By far the most common of the three types of drum in this country is the first named, the plain cylindrical type, and the least common is number two, i.e., two parallel drums on the shaft, one or both being loose. This is rather curious as most of the parallel drum winders supplied for abroad by manufacturers in this country have loose drums.

The advantage of the loose drum is that winding can be done from more than one level "in balance", both cages being wound from any particular level required to the surface without having to make a useless journey to the bottom level.

This saves time provided that winding is not done haphazard from all levels, that is to say, one wind from the bottom followed by one from an intermediate level followed by another wind from the bottom, then a wind from some other intermediate level and so on.

By way of example, consider a winder to wind from a maximum depth of 600 feet with an intermediate level at 400 feet from the surface the speed of wind being 20 f.p.s. maximum with acceleration, and retardation time 10 seconds each and 10 seconds for changing the truck. Winding from the 600 feet level, the net time of wind is 40 seconds and with 10 seconds interval, etc., time of cycle is 50 seconds and the number of winds per hour 72. This holds for both the single and the double drum winder.

Now consider the single drum winder winding from the 400 feet level; of necessity when one cage is at bank, the other must be at the 600 ft. level. Assume this to be the starting point, the cage at the 600 ft. level must be brought up to the 400 ft. level for loading purposes. This takes 20 seconds' running time, and 10 seconds will be required for loading. During this loading time the descending empty is suspended 200 ft. from bank. Winding is now continued, the loaded cage being taken to bank and the empty cage lowered to the 600 ft. level. This takes 30 seconds followed by 10 seconds interval for changing trucks. The total time of cycle is therefore 20 + 10 + 30 + 10 or 70 seconds, which gives approximately 52 winds per hour.

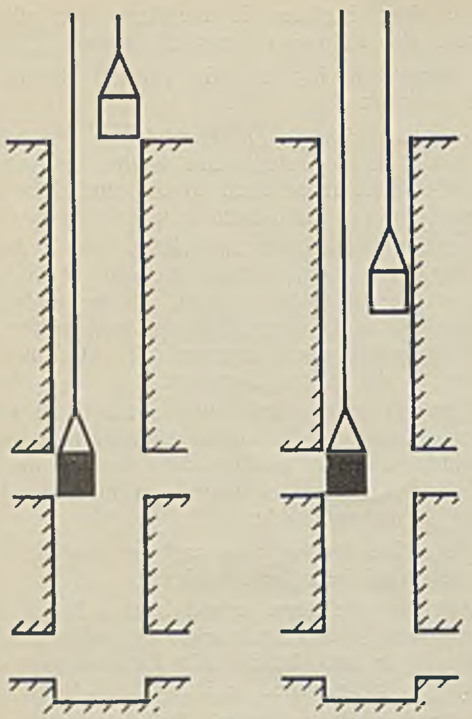


Fig. 1.—Relative Positions of Cages, winding from intermediate levels.

Now consider the double drum winder winding from the 400 ft. level. By unclutching and braking the loose drum, with attached cage at bank, the other cage can be brought up from the 600 ft. to the 400 ft. level. The loose drum is now clutched in and winding can be carried on from the 400 ft. level without either cage going below this level. The time required to wind the 400 ft. is 30 seconds and, with 10 seconds interval, the time of cycle is 40 seconds, giving 90 winds per hour, as against 52 for the single drum winder (see Fig. 1).

It will, therefore, be seen that the advantage is with the double drum winder when winding has to be done from an intermediate level. When only one or two consecutive winds have to be done from any intermediate level it is not worth while to alter the setting.

There is another reason why double drums are not so popular in this country as they are abroad, where skip winding is common. With cage winding it is essential to get the cage exactly opposite the landings, whereas with skips this is not so important a consideration. Even with multi-tooth clutches it is difficult so to arrange matters that the trucks will run into and out of the cages at top, bottom, and intermediate levels without a slight step-up or step-down ; that is to say, when the top cage is opposite the banking level, even though the bottom cage might be opposite its landing, it does not follow that the clutch is such that the bottom cage will be opposite the intermediate level landing when the top cage is at the top landing. Two inches rise or fall is about as accurate as can be expected even with large clutches and comparatively small drums. Friction clutches have been fitted but these are not recommended for winders owing to the danger of slipping when they have become worn.

It sometimes happens that owing to the angles of lead of the rope the diameters of the two drums must be greater than the diameter of the single drum, making the double drum winder still more expensive than the single drum. This feature will be explained later, but it will readily be seen that the inside flanges and the distance between them might take up space which could be occupied by the rope.

In spite of the foregoing disadvantages it is difficult to understand why double drums are not more common than they are in this country.

At a colliery in the Midlands an electric winder has been installed with double drums working to different levels continually throughout the day : in fact, the levels are changed about every quarter of an hour and now that the operator has had a little experience in clutching, he declutches, changes levels and re-clutches, in about a minute with no trouble at all.

When changing levels interlocking gear prevents the clutch being removed unless the brake is on and prevents the brake being taken off until the clutch is in.

On large winders the clutch is operated by a compressed air or an oil engine and, on small winders, by hand.

Cylindro-conical drums are only used when two levels have to be worked to, i.e., top and bottom. The rope to the bottom cage is on the small diameter, and to the top cage on the larger diameter. If the difference in these diameters be sufficiently great the weight of the downgoing empty cage at the start of wind would wind up the full cage, although on one side there would be the weight of the cage and empty truck or trucks, and on the other side the weight of the cage plus truck or trucks plus coal plus a length of rope equal to the depth of the shaft.

The object of the cylindro-conical drum is to reduce the peak loads on the motor at the start of the wind ; but it has a further advantage over the plain barrel drum in that towards the end of the wind, after the drum has been accelerated, the ascending cage rope is on the maximum diameter and the rope of the descending cage is on the minimum diameter, so that the kinetic energy of the drum, gearing, motor etc. helps the completion of the wind.

In designing a cylindro-conical drum it is usual to arrange to finish accelerating the drum and moving parts by the time the rope from the ascending cage reaches the end of the small diameter portion of the drum. Care must also be taken to have a uniform, or nearly uniform, rate of acceleration on both the small diameter and on the conical portion, so that the number of turns of rope on the cone has to be carefully chosen.

Not only are the peak loads reduced by this form of drum but the energy consumption is usually less and a smaller motor can often be used.

It should perhaps be mentioned that when a cylindro-conical drum winder is installed at a new pit the sinking can be done on a temporary parallel drum which can afterwards be built up to form the permanent cylindro-conical drum.

The conical drum has no advantage over the cylindro-conical, and it is heavier and more expensive.

With only one of the four foregoing types of drum is a balance rope permissible, viz., with the plain cylindrical drum : it is sometimes attached to reduce the initial peak load and by so doing it is possible to instal a smaller motor to do the work ; this, however, in the writer's opinion is a mistake ; the motor should be large enough to work without a balance rope whether one is used or not as it sometimes happens that it is desirable to remove the balance rope for a time in which case unless the motor is powerful enough to do the work the load would have to be lessened or otherwise the peak would be too much for the motor. It has sometimes been the case that when a balance rope has for some reason been removed, it has been discarded permanently : a balance rope is a nuisance.

Rope Angling.

The angles of lead of the winding rope have been mentioned : by this is meant the angles made by the rope between an imaginary line drawn from one of the head sheaves to the drum and at right angles to the drum shaft the rope being in the two positions corresponding to the beginning and to the end of the wind. The first angle is called the outside angle and the second the inside angle. In designing a suitable drum if these angles are too large the rope will not coil evenly. At the start, the rope will be spread out over the surface of the drum and at the end of the wind the rope would tend to coil back upon the rope already wound on, thus increasing the friction between turns.

A good rule is to limit these angles to 50 minutes outside the line of sheave, and 1 degree 36 minutes inside, or in other words, the distance from the centre line of the sheave to the rope at the start of the wind should not exceed 1/70th of the slope distance between the centre of the drum and the centre of the sheave ; similarly the distance between the centre line of the sheave to the outside of the last coil wound on at the end of the wind, should not exceed twice this amount, i.e., 1/35th of the slope distance. If these angles are exceeded it will be necessary to groove the drum, i.e., turn a spiral groove to form a path for the rope (see Fig. 2).

This question of rope angling often determines the diameter of the drum and is the reason why the small dynameter of a cylindro-conical drum is almost invariably grooved as it lies outside the safe angle.

Some colliery engineers specify that the drum must be sufficiently large to prevent over lapping of the rope paths, i.e., the centre portion of the drum barrel must not be occupied by both ropes. If one rope should coil on a part of the drum near the centre then the other rope at the end of the next wind must not occupy the same portion of the drum. Presumably, the reason is to prevent excessive wear of the wood lagging, when there is wood lagging, but it would rather appear to be more of a fad than anything else. In this country it is very unusual for more than one layer of rope to be wound on a winder drum, but abroad several layers are permitted.

Other considerations in determining the sizes of drum are diameter of rope the distance between centres of head sheaves, and, the most important consideration of all, the depth of shaft.

It is difficult to lay down any hard and fast rule for the minimum diameter of a drum as so much depends on the type of rope which is being used. For ropes of Langs Lay or Flattened Strand construction, it is considered quite good practice if the drum diameter is not less than 70 to 75 times the rope diameter ; while for ropes of Locked Coil construction the diameter should be not less than 80 to 85 times.

Calculations.

Having decided upon the size of drum the colliery engineer should make preliminary calculations and arrive at the approximate size of the winding motor. Even though, eventually, this matter is left to the manufacturer, the colliery engineer will have a check on the size of the plant, and if the motor output proposed by the supplier agrees approximately with the figure arrived at in the preliminary calculations there is less likelihood of any mistake being made.

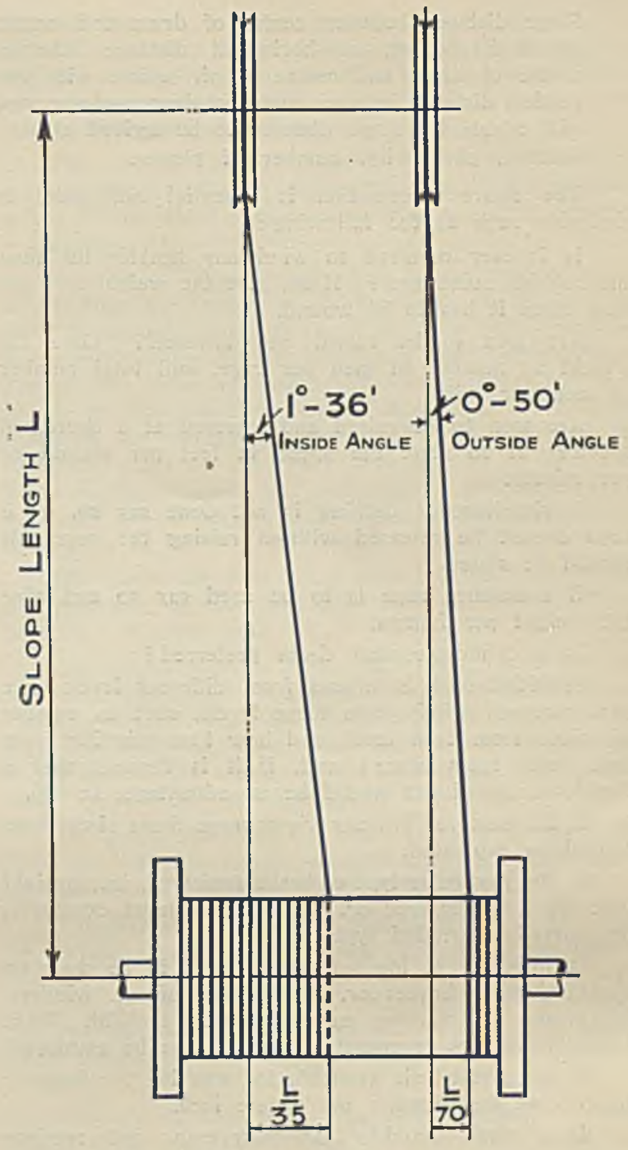


Fig. 2.—Shewing Rope Angles.

At this point may be mentioned the data which it is necessary for the manufacturer to have for calculating the size of the a.c. or d.c. motor or motors driving the winder, and for designing the winding engine.

Depth of wind.
Output per hour, i.e., tons of coal to be wound per hour.
Time of interval between winds for changing.
Weight of coal per wind.
Weight of rubbish per wind and how often this is wound.
Weight of each empty truck.
Number of trucks per cage.
Number of cages, one or two, or is there a cage and a balance weight ?
Weight of each cage or weight of cage and weight of balance weight.
Include in the weight of the cage the weight of the suspension gear.
Diameter of rope.
Weight per foot or per fathom.
Diameter of each head sheave.
Weight of each head sheave, if known.
Distance between centres of head sheaves.
Height of head sheaves above bank.

Slope distance between centre of drum and centre of head sheaves, or horizontal distance between centre of drum and centre of pit which, with the vertical distance between centre of drum and sheaves, will enable the slope distance to be arrived at.

Voltage, periodicity, number of phases.

The above information is essential but more is desirable such as the fullowing:

Is it ever required to wind any heavier lift than the rubbish mentioned? If so, give the weight and say how often it has to be wound.

Are men to be raised and lowered? Give the weight or number of men per cage, and total number of men per shift.

Are men to be raised and lowered at a decreased speed? If so state the speed in feet per second or per minute.

If simultaneous decking is not done say so, or if keps cannot be released without raising the cage this should be stated.

If a balance rope is to be used say so and give the weight per fathom.

Is a cylindro-conical drum preferred?

Provided coal is wound from different levels give particulars of winds from these levels, such as number of winds from each level, and how long winding from each level takes place; and, if it is thought that a double drum winder would be an advantage, say so.

If the enquirer has any views upon drum sizes these should be expressed.

Is any particular type of brake preferred, i.e., straight post type, caliper type or, the best but most expensive, the curved suspended type?

Is lowering of loads including men to be done on the mechanical brakes or, in the case of a.c. winders, by means of counter current braking? With Ward Leonard winders regenerative braking can be employed.

Is compressed air available for working the brakes? If so state the pressure per square inch.

Is a small stand-by air compressor and receiver required, the former driven by an electric motor, or will the mine air supply be available always? Perhaps oil brake engines are preferred: in any case it is always better to specify requirements.

If the plant has to be installed underground the limiting dimensions and weight of the heaviest part which can be handled should be stated. Also whether the electrical machines and apparatus have to comply with paragraph 132 of the Coal Mines Regulations, i.e., whether flame-proof equipment is required.

Possibly the winder motor will work on high tension a.c. supply but the brake magnet and the auxiliary air compressor motor or oil pump motor for the brakes certainly will not, so that unless a low tension supply is available a small three-phase transformer should be supplied with the winder. This should be mentioned.

Must the peak demand on the supply be kept below a certain maximum? If so, state maximum demand permissible. Is there a preference for any particular type of winding plant or is this choice to be left to the manufacturer?

Do not send out a vague enquiry, it is not fair to the manufacturer. If the enquirer has any decided views on the type of electric winder best suited for the conditions in question or would prefer certain types of component parts it is very desirable for these views to be stated.

Calculations are usually made and Brake Horse Power Output Diagrams drawn for each set of conditions to determine the size of the motor: the diagrams so prepared usually comprise:

1. B.H.P. output of motor winding coal.
2. „ „ „ „ stone or rubbish
3. „ „ „ raising men.
4. „ „ „ lowering men.

Diagram Number 2 is almost invariably more severe than Number 1, but it often happens that the stone winding is only done for an hour or so during the day so that this service can be regarded as an overload condition. If the motor will work continuously to the coal winding diagram without exceeding a temperature rise of say 40 degs. C., provided the stone winding diagram is not abnormal in any way and has not frequently to be worked to the motor would have a natural overload capacity of 25% for two hours, and its temperature would not exceed a safe figure even though this overload followed a day's working to the coal winding diagram.

Diagram 3, raising men, seldom affects the size of the motor as it is usually less severe than the normal coal winding: but Diagram 4, lowering men, decides the size of the controller in an a.c. winder if counter current braking is to be employed. Winding men at a reduced speed can easily be done with Ward Leonard control. A small switch is fixed on the driver's platform and if he closes this switch a permanent resistance is inserted on the winding motor field so that if he uses his controller lever in the same way as for coal winding he can never exceed the predetermined "men winding" speed. With three-phase winders, however, the only way the maximum winding speed can be reduced is by increasing the resistance in the rotor circuit, which means that a considerable amount of energy has to be dissipated in the controller, and so, not infrequently, the controller has to be larger than it would otherwise be.

Similarly if counter current braking is employed with a three-phase winder, a larger controller may be necessary, as power is taken from the line corresponding to the power given out by the descending load, and both have to be dissipated in the controller.

Regenerative braking is never resorted to on a.c. winders as this is only practicable when the moter runs above synchronous speed. It is too dangerous altogether to run at that speed with vertical shafts, especially as the controller lever has to be brought back to the reverse position for stopping, during which time counter current braking must be used.

With Ward Leonard winders it is only the converter set which overspeeds when regenerative braking takes place; which means that it is quite safe, and it is economical too.

There are two principal types of electric winders: the three-phase winder and the Ward Leonard winder.

Three-Phase Winders.

In the first case the motor is a slipring induction motor usually driving the drum through a flexible coupling and gearing. Winders have been installed, and are still working after more than 20 years' service, where a three-phase slipring motor is coupled directly to the drum shaft; but this means a large slow speed motor with lower efficiency than a quicker running motor and gearing, the power factor of such a machine is considerably lower also.

The speed control is by means of a resistance in the rotor circuit. In the case of small motors, up to say 50 h.p., the controller is of the drum type or tramway type with metallic resistances. Even larger motors have this type of resistance, the controller then being of the contactor type, but such motors are usually installed only in those cases where cooling water is not available for the electrolyte of the liquid controller.

Liquid controllers are invariably used for large winder motors. The metallic type of resistance becomes very bulky for large winders, whereas the liquid type can be kept down to a reasonable size by cooling the electrolyte. The controller or rotor regulator has a bank of tubes through which cold water is pumped if a supply under pressure is not available. Usually five gallons are required per h.p. dissipated per hour so that a small pump is sufficient even for a large controller. The electrodes move into or out of the electrolyte, decreasing or increasing the resistance in the rotor circuit. Some three-phase winders have fixed electrodes and moving electrolyte, i.e., the electrolyte is pumped from one chamber to another in the controller, the control being by means of a valve or weir. These are not now common.

The stator reversing switch for large three-phase winders is of the contactor type either oil-immersed or air-break for both H.T. and L.T. supplies. A controller lever is mounted separately in a frame to which is attached a master switch. The lever operates the rotor regulator directly by a rod or rods and levers, and at the same time operates the master switch which controls the contactor coils of the stator reverser. On very large winders the driver has a servo-motor, or compressed air engine, or oil assisting engine, to assist him to operate his lever.

The amount of energy dissipated in the controller of a three-phase winder in bringing the motor up to full speed is considerable. During the acceleration period more energy is dissipated in the controller than is taken by the motor itself, and this is one of the disadvantages of an a.c. winder. Again, as previously mentioned, considerable energy is wasted during braking by counter current.

There is another disadvantage and that is that only with exactly similar loads will the speed correspond with the position of the controller lever between "no speed" and "full speed"; i.e., if stone is being wound the controller lever will not be in the same place for a certain speed as it would when coal is being wound at the same speed, because the speed varies with the torque. Hence it is not possible to fit cam gear to regulate the driver's control lever, as is the case with the Ward Leonard winder, but much has to be left to the skill of the operator.

Ward Leonard Winders.

The second principal type of winder in use is that where Ward Leonard control is used. The winding motor is a direct current, separately excited, shunt wound motor with its brushes directly connected to the brushes of a variable voltage, separately excited, generator running at constant speed. The speed of the motor is directly proportional to the voltage applied to the armature, so that by varying the excitation of the generator by a field regulator the armature voltage is varied and consequently the speed of the winding motor is varied.

Speed control is therefore simply a question of moving the field regulator by means of a lever, and the direction of rotation can be reversed in the same way. The regulator or controller is coupled by means of a rod or rods and levers to the driver's control lever, and any position of the lever corresponds to a certain definite speed, practically irrespective of the load or whether the load is being raised or lowered.

The variable voltage generator is usually directly coupled to an induction motor, and the exciter is also driven by this slipring motor, the three machines forming a converter set.

Here there is no energy lost in the controller in accelerating the motor or in braking. If the control lever is brought back to the "off" position from the full speed position electric braking is done automatically, because the winding motor acts as a generator and speeds up the convertor set to above the synchronous speed of the induction motor, which then acts as an induction generator and pays back current to the line. When lowering loads this regenerative braking is considerable and of course, it is the most economical kind of braking of all.

The controller only deals with the field current of the generator so that even with very large winders the controller is quite small.

Advantage is taken of the fact that the position of the controller lever corresponds with the speed and camgear driven from the drum shaft is utilised, one set to prevent the driver from accelerating too quickly at the start of the wind, and one set to return the control lever to the "off" position at the end of the wind.

The disadvantage of the Ward Leonard winder is its first cost which is usually more than half as much again as that of the equivalent three-phase winder.

The winding motor of a Ward Leonard winder can be directly coupled to the drum shaft, in which case it has one bearing at the commutator end, and a half solid coupling at the driving end for coupling to a similar half-coupling on the drum shaft near to one of the drum shaft bearings. With this arrangement no gearing is required.

Winders of this type have been running for over 20 years and the cost of upkeep has been very low indeed, as only the brushes have had to be renewed; not even the bearing brushes have had to be replaced. The motor can also be of the two bearing type driving through a coupling and gearing. The convertor set, as stated previously, is usually driven by an induction motor but it is sometimes driven by a synchronous motor or an asynchronous-synchronous motor. Where a synchronous or an asynchronous-synchronous motor is used it is generally necessary to provide a separate exciter for the d.c. excitation of the motor.

Ilgner Winders.

When it is desired to limit the peak loads on the supply (as in the case of a large winder on a supply system where the power station is comparatively small) a flywheel is coupled to the convertor set and the sliprings of the induction motor driving the set are connected to an automatic slip regulator. This slip regulator is a liquid starter of the moving electrode type, the electrodes being mounted on a spindle which is geared to an a.c. "torque" motor. This torque motor is of the squirrel cage type and it is connected to the secondary winding of a current transformer, the primary winding being in the stator circuit of the induction motor driving the convertor set.

When the peak loads come on the winding motor, these are reflected in the current taken from the supply and as this current rises, so also does the secondary current of the transformer: therefore the torque motor turns the spindle of the starter electrodes against a spring or weight, and the electrodes move further out of the liquid, thus causing the motor of the convertor set to slow down owing to the extra resistance inserted in its rotor circuit. This slowing down allows the flywheel to give up some of its stored energy to the variable voltage generator.

If the flywheel were made heavy enough, the energy taken from the line would be a "straight line" with no peak loads whatever, although the winding motor would have heavy peak loads. A lighter flywheel would only partially equalise the demand on the supply. The drop in speed of the flywheel is usually arranged to be about 12½% to 15% from the full load speed.

Where this system is installed an automatic shunt regulator is fitted to keep the exciter voltage constant; otherwise, owing to the exciter dropping in speed 12½% to 15% every wind, its voltage would vary considerably and the Ward Leonard control would be very erratic.

Safety Devices.

The emergency brakes are applied through any or all of the following emergencies:

(1) Any time by hand should the driver require to do so.

(2) In case of failure of current: this is done through the plunger of a brake magnet falling.

(3) In case of overwind. Limit switches are fixed on the depth indicator and, or, on the pit head structure, and whenever one of these is opened the current to the brake magnet is cut off. On L.T. three-phase winders the limit switches trip the no-volt coil on the main switch pillar and, as the brake magnet is connected to the main oil switch in a parallel circuit to the motor circuit, the plunger is released. On H.T. three-phase winders the brake magnet is tripped through a separate contactor switch. Mechanical overwinders apply the brakes directly, but in this case arrangements are made to shut off the current to the motor when the brakes come on.

(4) Whenever the winding speed exceeds a predetermined maximum. Sometimes a centrifugal overspeed switch is fitted (on the shaft which is coupled to the motor shaft) which trips the brake magnet in exactly the same way as the limit switches. Usually, however, an overspeed device is installed which is either a separate piece of apparatus or forms part of the mechanical overwinder: this device not only trips the emergency brake gear directly, or through the brake magnet in case of maximum speed during the major portion of the winding time, but also should the driver fail to retard at the proper time as the cage approaches the bank.

(5) Failure of air pressure or oil pressure. A small piston ceases to hold up a weight which falls and trips the emergency gear or alternatively opens a switch like the limit switch previously mentioned.

(6) There are always overload releases fitted on the main switch pillar.

With Ward Leonard winders having flywheel convertor sets the brakes are not applied should the main supply current fail as advantage is taken of the kinetic energy of the flywheel to complete the wind.

A maximum relay in the main armature circuit to the winding motor trips the brake magnet in case of excessive current, and a minimum relay on the d.c. switchboard also releases the brake magnet should the excitation current fail.

Cams dirven from the drum shaft through gearing operate roller levers which are connected by a rod or rods to the driver's controller lever and, during the deceleration period, move the controller lever back to the neutral position whether the driver does so or not. Additional cams prevent the driver from accelerating too rapidly at the start of a wind, thus preventing excessive peak loads.

Whenever the emergency brakes are applied an emergency switch is opened and cuts off current to the winding motor on both three-phase and on Ward Leonard winders.

It is the superiority of control obtainable with electric winders which, perhaps more than anything else, has made them popular with engineers.

Over twenty years ago a colliery engineer in this country allowed his wife to handle the levers of a Ward Leonard winder and let him down the pit and wind him up again, although she had never before seen a winder in her life. Some wives might like to have the same chance with a real old steam winder!

In conclusion the author wishes to thank the English Electric Company for the loan of the lantern slides and also to express his indebtedness to Mr. J. Kirkwood for his assistance in revising the manuscript of this paper.

NORTH OF ENGLAND BRANCH.

Frequency Standardisation: Notes for Colliery Engineers.

J. E. LAMBERT.

(*Continued from page* 197).

Switch Adaptors.

The question of temporary switchgear alterations in order to split up the various circuits on to 40 cycle or 50 cycle supplies is one which requires careful consideration. Normally it would be necessary to break the busbars on the distribution gear, which in many cases is compound filled, and to use a series of jumpers. This entails very tedious work with the risk of broken insulators, damage to insulation and mis-connections.

With a view to eliminating a considerable amount of work, and making use of the fact that a large amount of the distribution switchgear met with in collieries is made up of mining type draw-out panels, switch adaptors have been designed by leading switchgear manufacturers to suit the switchgear of their manufacture in use in and about the mines.

By the use of these switch adaptors it is suggested considerable flexibility is obtained. The method adopted is to provide the fixed portion of a complete switch unit of a similar type to the existing unit and have this set in any available space near to the existing unit. The 50 cycle supply is connected to the temporary stand in the normal way whilst the outgoing contacts are connected to an appropriate switch adaptor by means of a suitable length of multi-core semi-flexible armoured cable.

The existing switch-unit is then removed from the permanent stand and replaced by the switch adaptor. The existing switch unit is erected into the temporary stand and by this means the 50 cycle supply is connected to the outgoing feeder concerned with exactly the same protection and without displacing any of the existing cables.

The switch adaptor itself is reversible, provision being made for locking it into position so as to make it impossible for it to be withdrawn except by an "Authorised Person."

By making use of a series of adaptors in a similar manner, a whole complement of feeders can be changed over in sequence and any available space can be chosen to house the temporary stands, if suitable lengths of flexible armoured cable are supplied. Figures 16 and 17 illustrate the switch adaptor of a well-known maker of mining type switchgear.

Machine Mining Equipment.

Machine mining equipment is a class of plant which moves its position frequently in and about the mine and which is generally in operation at sometime during the week-end. It is therefore proposed to carry out the changeover of this class of plant as far as ever possible by making use of replacement plant of an interfrequency type. Machine mining plant in general lends itself exceptionally well to interfrequency working and it is a decided advantage, from a changeover operation point of view, if the coalcutters, in particular, can be modified previous to main changeover operations, leaving a gear change (if any) to be carried out later, which change can be easily done *in situ*. There are, however, exceptions and with a view to simplifying the changeover of these types there will be available a number of interfrequency coalcutters which can be lent out for use with a view to liberating the existing machines for modification.

Provision has been made on the machines which can be lent to meet as far as possible the varied conditions they may be called upon to operate under; i.e., they have been provided with jibs of varying lengths and, where the machines are of the arcwall type, trams are available of suitable design to enable the gauge to be varied to suit the different collieries on the North East Coast; also, packing pieces are available for the adjustment of cutting levels.

Pumping Plant: Centrifugal Pumps.

The various pumping plants likely to be met with in the collieries on the North East Coast practically all call for individual consideration and in many cases it has been found that the best method, with a view to avoiding any liberties being taken with the pumping plant, is to arrange to carry out the changeover by means of interfrequency pumps. The subject of interfrequency pumps has been dealt with in a previous Paper and therefore it is not proposed to deal with any aspect of the problem other than the practical application of the interfrequency pump. The duty on some of the pumping plants is subject to variation according to the season of the year, and whilst in one part of the year the problem may be exceedingly difficult, if a choice of time is available, advantage can be taken of the seasonal conditions. The only method by which this advantage can be obtained is by the installation of an interfrequency pump previous to main changeover operations, leaving only modifications to be carried out at the time of changeover.

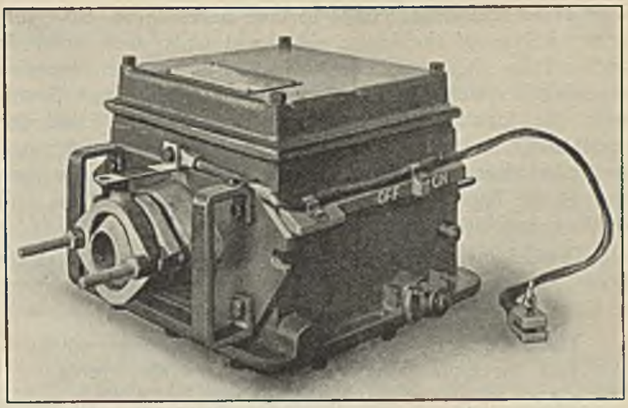


Fig. 16.

Again, heavy pump house alterations may be avoided by being able to select a holiday period to carry out a pump replacement scheme; or advantage can be taken, where a pump ordinarily is at certain times out of action for several days during cleaning or routine overhaul, to instal a new unit, leaving only modifications to be carried out during main changeover operations.

Mobile Workshops.

In the course of a main changeover circumstances are likely to arise whereby the workshops of the consumers will not be available or, alternatively, may be insufficiently equipped to deal with the various operations likely to be called for under changeover conditions. With a view to catering for this difficulty a mobile workshop will be available for the use of consumers where these conditions arise.

A short description of this Mobile Workshop no doubt would be of interest and a short abridged specification is as follows:—

It is of the 10-ton, two-wheel (fixed), drop frame, pantechnicon type carrier fitted with half lay-down sides and ends specially fitted for use as a portable workshop. The lower halves of the hinged sides and ends let down on to special supports to act as platforms fitted

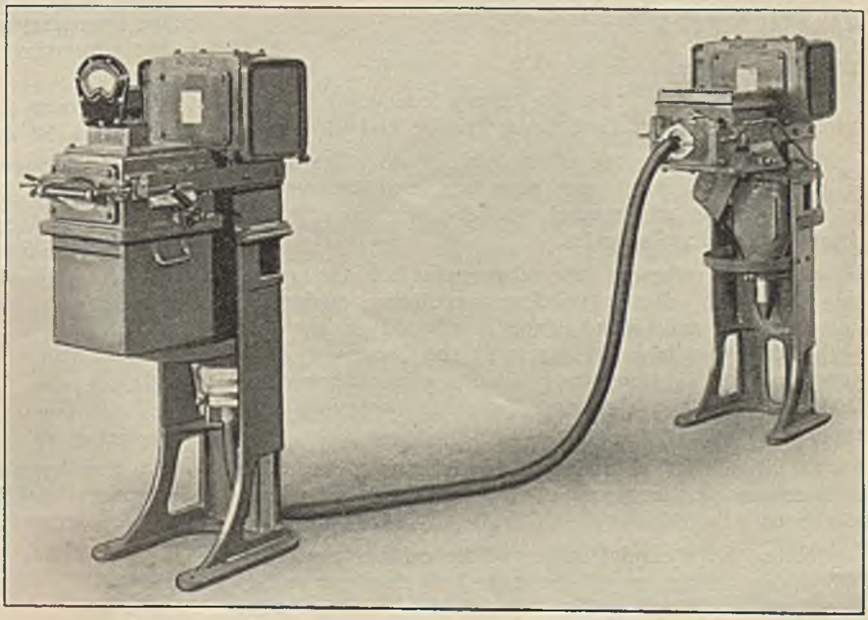


Fig. 17.

with reinforced outer edges to take bench vices, etc. The upper halves of the hinge sides and ends open upwards and act as shelters, being fitted with weather curtains reaching to below the platforms. In the bow front, over the turntable, shelves and drawers are fitted for small tools, bolts and nuts. It is also equipped with two swing girders for chain blocks, one at the side and one at the back, these to serve principally the lathe and drilling machines respectively.

Provision is made longitudinally under the vehicle floor for carrying bars, piping, etc., and, in addition, a slung locker for ropes, blocks, etc.

The inside of the vehicle is wired for internal lighting and three-pin plug points for portable tools.

Special trestles are provided with the vehicle to support the turntable when the motive unit is removed, four screw jacks being provided to take the weight of the body when the workshop is in operation.

At the fore-end of the wagon is one petrol-driven generator set, 220 volts d.c., 15 k.w. capacity, with petrol and oil reservoirs, control board instruments and wiring for fixed tools.

The workshop is equipped with:—

One 10½ ins. centres sliding, surfacing and screw-cutting gap lathe, with screw-cutting motion feed.

Complete with the following accessories:—

One 30 ins. dia. face plate.

One 12 ins. dia. four-jaw self-centring chuck.

One pair of Morse taper centres.

One full set of screw-cutting chain wheels.

All the necessary handles and spanners.

One combined sensitive radial drill with 38 ins. radius, drilling 0 in. to 1¼ ins. dia.

One key-seating machine cutting 0 in. to 1¼ ins. × 12 ins. long.

One 9 ins. disc shaper complete with slotting attachment.

One 20 ins. single wheel dry grinding machine.

One double-end grinder.

And various small tools, including an oxy-cutting plant.

The workshop would be drawn into position at the colliery by means of a Scammel motive unit fitted with towing hooks fore and aft.

Changeover Operations.

It is suggested that the mines connected to the system on the North East Coast can be classified as:—

(1) Mines which are of such a size that the whole of the electrical plant and necessary modifications can be completed in any normal week-end without any provision for duplicate supplies.

(2) Mines whereby the changeover of the essential plant, i.e., electric winders, ventilating equipment, main haulage and main pump, is effected in the first week-end, by suitable arrangement the remaining plant could receive a temporary supply from Frequency Changers until the changeover of that particular mine was completed.

(3) Mines where a definite duplication of supplies is necessary to sectionalise the plant for changeover operations.

[Note. By a careful survey of the existing conditions and taking advantage of the types of plant previously described a difficult colliery changeover can in many cases be simplified].

Typical Colliery Changeover. (Cat. 3).

It is proposed to attempt to describe a typical colliery changeover; an involved proposition when time and space are so limited. A start will be made at the point where the whole of the replacement plant has been delivered to the colliery, transported to a suitable position for the changeover and checked up as far as possible.

Figures 6 and 7 shewed a Colliery layout and it is now proposed to describe a method of changeover proposed, making use of the various types of plant available, in order to minimise the risks and to simplify the actual operations of the changeover. Figure 6 shews the colliery surface plant and it will be seen that:—

(a) The busbars in the consumer's chamber have been duplicated to make available 40 and 50 cycles supplies, and an additional panel added for the control of the duplicate shaft cable at 50 cycles.

(b) A delta/parallel star fan motor installed on the main ventilating equipment with an extra pulley available to suit the ultimate speed. By this method it has been possible to select a holiday week-end previous to main changeover operations to carry out the changeover of this important plant.

(c) In No. 1 Substation: (i) 3 switch stands (3000 volts) similar to those existing have been erected and connected to the live side of one of the incoming feeders, the stands being complete with three suitable switch adaptors; (ii) 3 switch stands (L.T.) similar to those existing but not connected and complete with switch adaptors.

This comprises the temporary work in connection with the surface plant.

Sequence of Changeover (Surface).

(1) Change over new sinking plant.

Connect the temporary 50 cycles busbars in Consumer's chamber.

(2) Change over electric winder.

Modify fan.

Connect the temporary 50 cycles bars in Consumer's chamber.

(3) Connect No. 1 switch feeder to 50 cycles bars. Remove switches controlling transformers and washery plant from their permanent positions and re-erect in the temporary stands, replacing these by switch adaptors; the temporary stands being fed at 40 cycles by No. 2 feeder.

Change over air compressors and Brickworks which will receive a 50 cycles supply through No. 1 feeder.

(4) Change over washery motors and replace the switch in its permanent position.

(5) Replace one transformer switch back to its permanent position and remove the corresponding low tension switch from its permanent position and erect in one of the low tension stands, replacing the switch by a switch adaptor. This gives a 50 cycles supply to the low tension temporary stands.

Remove one feeder switch to Screens and Dry Cleaning plant and re-erect in the 50 cycles temporary stand replacing by a switch adaptor.

We now have a 40 cycles and a 50 cycles supply at these premises and by suitably splitting up the changeover of the Screens the dry cleaning plant can be completed.

(6) Remove one Shops Feeder and re-erect in the remaining temporary L.T. stand and replace by switch adaptor.

Changeover the Shops Motors on this feeder.

(7) Replace all the Switchgear back into its normal position.

Disconnect the temporary stands and complete the change-over of the remaining motors.

All the Reyrolle panels in the Consumer's Chamber of the Substation with the exception of the 40 cycles Shaft Feeder will now be connected to the temporary 50 cycles bars.

Underground.

Figure 7 shews the underground plant of the same colliery. It will be seen that the following preparatory work has been carried out:—

A temporary shaft cable has been installed looping in at each seam through: one switch stand complete with switch adaptor at the main coal seam; two switch stands complete with switch adaptors at the Yard Seam; one switch stand complete with switch adaptor built on to the inbye side of the existing switch board (but not at first electrically connected).

Main Coal Seam.

On the main haulage a Delta/Parallel Star induction haulage motor has been installed to run 25% slow, the conditions being suitable; also inbye three single-stage inbye pumps have been installed of interfrequency design, leaving only impellors to be changed over under main changeover operations.

Yard Seam.

All the coalcutters and conveyors are fitted with interfrequency motors leaving only gear changes (if any) to be carried out under main changeover operations.

Two single-stage interfrequency standage pumps installed previous to main changeover operations leaving only the impellors to be changed.

Low Main Seam.

A Delta/Parallel Star induction motor has been installed on the treble ram pump, the pump to run 25% slow during changeover operations.

SEQUENCE OF CHANGEOVER.

Low Main Seam.

(1) Change over all Inbye plant.

Remove Inbye Feeder Switch from existing stand, plug in Switch Adaptor, and re-erect existing Feeder Switch into the temporary stand provided which is in turn fed by the 50 cycles shaft cable.

(2) Change over—one 150 h.p. Main Haulage Motor.

One 150 h.p. Centrifugal Pump.

One 15 h.p. Creeper.

One 10 h.p. Shaft Landing Hauler.

Change links on treble Ram Pump motor.

Isolate and lock off the Low Main Feeder Switch in the Yard Seam Switch House.

Replace the Low Main Inbye Feeder Switch into its normal position and connect the temporary stand to the busbars of the Low Main Seam Switchboard.

The Low Main Seam is now changed over to 50 cycles working, being fed by the temporary shaft cable.

Yard Seam.

(1) Changeover the 100 h.p. Centrifugal Pump.

To obtain a 50 cycles supply remove the existing switch from its permanent stand, replace by Switch Adaptor and re-erect existing Switch into the temporary stand fed by a 50 cycles supply.

(2) In a similar manner changeover the 90 h.p. Main Haulage.

(3) Change over the Inbye Plant.

Modify the Standage Pumps.

Changeover the 20 h.p. Creeper.

Isolate and lock off the Yard Seam Feeder Switch in the Main Coal Switch House.

Replace the Feeder Switches for the 100 h.p. Centrifugal Pump and 90 h.p. Haulage into their permanent positions.

Close the Low Main Feeder Switch on the Yard Seam Switchboard.

The Low Main and Yard Seams are now on 50 cycles.

Main Coal Seam.

(1) Change over and modify the Inbye Plant.

In a similar manner as before obtain a 50 cycles supply for this feeder by the temporary stand and switch adaptor provided.

(2) Change the links on the 200 h.p. Main Haulage.

Changeover the creeper and "back of the shaft" hauler.

Replace Inbye feeder switch into permanent position.

Disconnect the temporary stand at the Low Main Seam Switch House.

Connect the 40 cycles Shaft Cable to the 50 cycles supply.

Close the Yard Seam feeder switch.

All the underground plant is now on 50 cycles and any temporary work can be removed and the plant left in its permanent state, but on 50 cycles supply.

Typical Main Pumping Plant Changeover.

Let us assume Figure 18, Section 'A' illustrates the layout of the main pumping plant at a typical North of England Colliery. The conditions are such that a direct replacement of this plant as shewn by suitable 50 cycle plant could not be undertaken without extension of the Pump Room at the Main Seam, a difficult operation owing to the existing Pump Room being very near to the shaft; the idea being to instal one new unit complete previous to Main Changeover.

After negotiation the Consumer expresses a wish to be afforded the opportunity of modifying the pumping layout, with a view to future requirements, to those indicated on Fig. 18B; this would be agreed, subject to mutually satisfactory arrangement regarding the Consumer's and the Undertaker's respective quota of the cost involved, and at first sight the Changeover problem appears more difficult than ever.

After a careful survey had been made, however, it would be suggested that use might be made of interfrequency pumping plant with the result that Pump Room extensions would be rendered unnecessary as practically the whole of the work could be carried out previous to Main Changeover; Figure 18C shews the conditions just previous to Main Changeover, if this were adopted.

It will be seen that a 105 h.p. interfrequency pump has been installed at the Bottom Seam, delivering direct to the Surface and that by so doing a space previously occupied by the 80 h.p. pump in the Main Seam has been liberated.

The 80 h.p. pump has been removed and the first of two new 305 h.p. units has been installed of interfrequency type; this in turn has liberated one of the existing 220 h.p. 40 cycle pump sites so that a new 305 h.p. 50 cycle unit can be erected on it.

The position therefore would be that at the Change-over week-end the 105 h.p. pump at the Bottom Seam and the 305 h.p. interfrequency unit at the Main Seam require to be modified whilst the second 305 h.p. 50 cycle unit requires to be placed on load, leaving only the third 305 h.p. pump to be installed in place of the 220 h.p. 40 cycle unit at any convenient time afterwards.

It will be seen that this application of interfrequency equipment would thus make it possible for a complicated pumping plant replacement to be carried out with the minimum risk and without interfering with Main Change-over operations at the Colliery concerned.

These Notes are incomplete but outline some of the Changeover methods likely to be adopted on the North East Coast by Authorised Undertakers, who welcome constructive criticism and are prepared to take the fullest advantage of any suggestions Colliery Engineers and others may care to proffer.

APPENDIX 'A.'

PORTABLE FREQUENCY CHANGERS.

Starting Up and Putting On Load.

The Tirrill Regulator must be switched out of circuit.

The field rheostats must be turned right back in the 'Lower' direction and all switches must be open.

The rotation of the set is clockwise when viewed at the terminal board end.

Before starting up all the cubicle doors must be closed and locked with the special key provided with each cubicle and applicable to that cubicle only.

Starting. The motor is started up by the 'Three Breaker Method' of starting and the operation is as follows:—

(1) After closing and securely locking all the cubicle doors, insert the key in the lock located at the starting switch end of the rotating interlocking bar on the input cubicle. Turn the key in a clockwise direction and press the small black handle on the lock upwards and towards the cubicle. It will then be possible to close the starting switch No. 1. This makes the motor alive and releases the lock on the neutral switch No. 2.

(2) On closing the neutral switch the starting auto-transformer windings are starred. (See diagram of connections). The motor starts up as an induction motor and the interlock on the running switch No. 3 is released. When the motor reaches approximately synchronous speed the motor field switch on the Output cubicle is closed and the rotor amperes adjusted to a figure suitable to the voltage in accordance with the table hereunder. This brings the set into synchronism.

(3) The handle of the running switch may now be set ready for closing. Before it can be closed, however, the handle on the sliding interlocking bar must be pulled over to the left-hand side to the full extent. This trips the neutral switch No. 2. At the same time the running switch No. 3 must be closed without delay. As soon as the spark contacts on this switch close the starting switch, No. 1 is automatically tripped and the starting auto-transformer is cut out of circuit. *Should the running switch trip in closing it must on no account be closed a second time without going through the whole sequence correctly again, starting with No. 1 switch.* The reason for this is that as soon as the neutral switch No. 2 trips the set begins to lose speed rapidly and if there is delay in closing the running switch No. 3, the set will drop out of synchronism and a heavy kick and severe arcing at the contacts will take place when the running switch is closed late.

The k.v..a. rating of each machine as a motor is given as 700/560, i.e., 700 k.v.a. at 440 volts and 560 k.v.a. at 650 volts. The k.v.a. may be of any value not exceeding 700 k.v.a. at the intermediate voltages, provided the value of the field current will give satisfactory results.

The approximate field currents are as follows and will serve as a guide when starting up:—

40 cycle, 8-pole Machine.		*50 cycle, 10-pole Machine.*	
Supply Volts.	*Rotor amps.*	*Supply Volts.*	*Rotor amps.*
440	55.9	440	45
500	68.8	500	65.5
550	54.6	550	55.2
650	72	650	75.2

Synchronising. When the alternator field switch is closed and the voltage regulated the set is ready for load or for synchronising. Before the set can be synchronised with another machine or source of supply, the 50 cycle stator must be rotated by means of the rocking gear until the exact phase angle has been obtained.

TIRRILL REGULATOR.

When the set is running and the alternator field is adjusted to give the required voltage, the Tirrill regulator may be put in circuit. The method of doing this is as follows:—

(1) See that the cut-out control relay switch i.e., the single-pole switch on the left-hand side of the regulator base, is open.

(2) See that the multi-pole cut-out is set.

(3) Close the isolating switch on the regulator panel. See that the Tirrill is connected to the generator the voltage of which it is desired to control.

(4) By means of the regulating rheostat balance the arm of the a.c. control magnet and see that the relay contacts are just trembling. This can be done by a system of 'bracketing,' i.e., by turning the rheostat in one direction until the relay contacts close and then turning it rapidly in the other direction until they open, gradually reducing the amount through which the rheostat is turned.

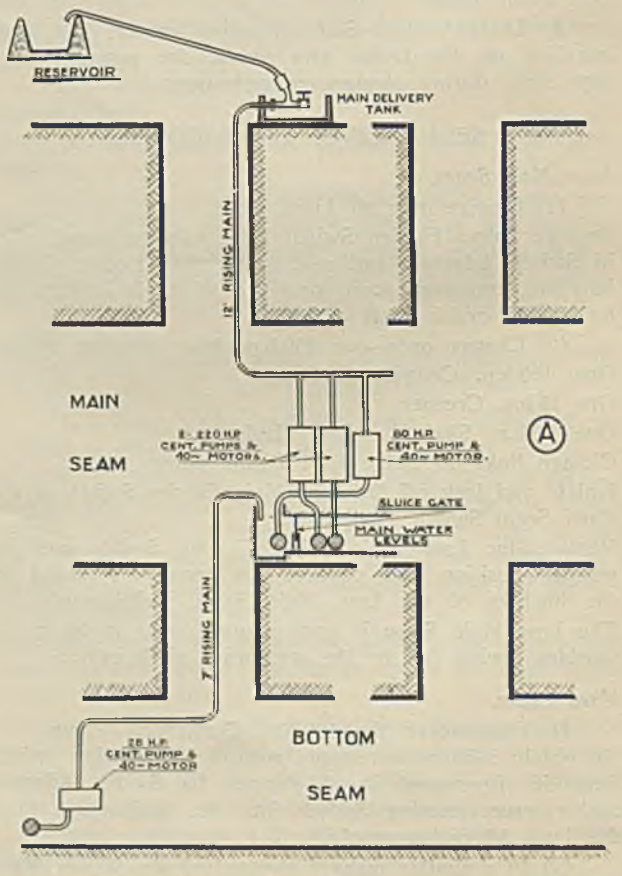


Fig. 18*a*.

(5) Close the single-pole switches at the bottom of the regulator sub-base.

(6) Gradually turn the exciter field rheostat down until it is in the 'Tirrill Position.' The regulator will now control the voltage of the generator throughout the whole range of its load.

(7) Close the cut-out control switch, first making certain that the moving contact 88, of the cut-out control relay is mid-way between the two fixed contacts 87. (Refer to Diagram of connections).

To take the Tirrill regulator out of circuit:—

(1) Open the cut-out control relay switch, i.e., the single-pole switch on the left-hand side of the regulator sub-base.

(2) Gradually raise the exciter field rheostat until the relay contacts on the regulator just stop beating.

(3) Open the single-pole switches at the bottom of the regulator sub-base. The generator is now out of control of the regulator.

(4) Open the isolating switches at the bottom of the regulator panel.

When operating two sets in parallel each with its its Tirrill regulator functioning the following should be noted:—

When starting up two or more Tirrill regulators, each fitted with a compensating coil to enable them to run in parallel, one regulator should be put into service with its compensating coil open circuited by means of the switch provided. The second generator should then be run up to normal speed and volts and synchronised with the machine that is already on the busbars.

Close the compensating switch and place adjustment switches 'A' and 'B' hard over to the right so that full compensating effect is obtained: then balance the lever of the a.c. control magnet so that the relay contacts are just trembling. Gradually turn down the exciter field rheostat towards the 'Tirrill Position' keeping a close watch on the power factor meters. If the power factors of the generators begin to move widely apart the compensating coil connections are wrong and the exciter field rheostat should be turned to its original setting.

It is important to note that the regulator which is on first should have its compensating coil open-circuited and the regulator which is to be put in service afterwards should have its compensating coil *in* circuit. Similarly, when taking the regulators off in order to shut down the generators, the regulator(s) that have their compensating coils in circuit should be taken out of service first and afterwards the regulator which has no compensating coil in circuit. The regulator with its compensating coil in circuit should never be taken off last as such a procedure may cause either a rise or fall in the line voltage.

The Tirrill Regulators must on no account be interfered with.

Discussion.

Mr. BURNS.—I commend Mr. Lambert's Paper to you as an example of thoroughness and clear thinking on a subject that can be involved; there have been other Papers dealing with Frequency Standardisation and allied topics, all of them interesting in their way, but here is a contribution by an engineer who before very long will be called upon to overlook, at close quarters, the carrying into effect of the various operations he has described. I feel sure you agree that what Mr. Lambert has had to say to us carries conviction that careful forethought is being devoted to these colliery changeover problems.

I have cause to be directly interested in this matter and so should like to join with Mr. Lambert in the

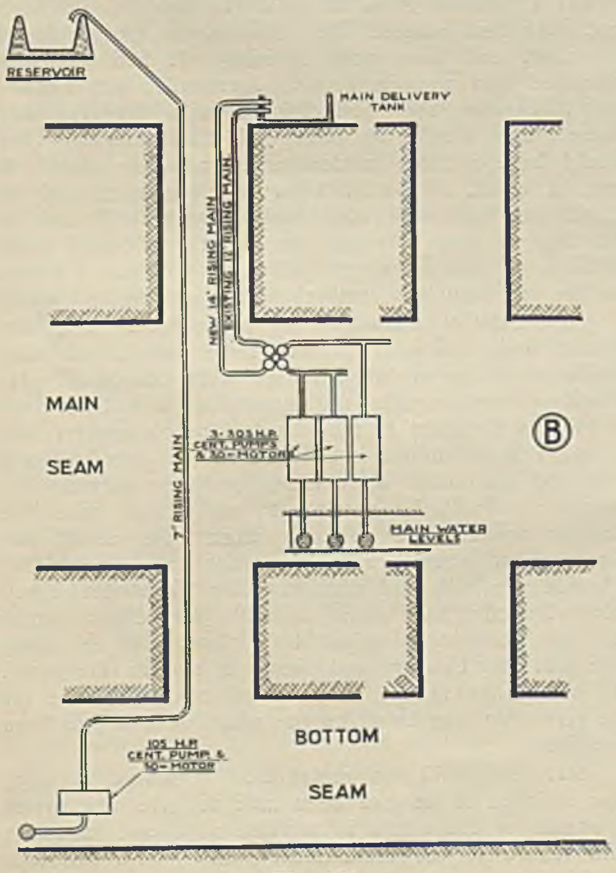


Fig. 18*b*

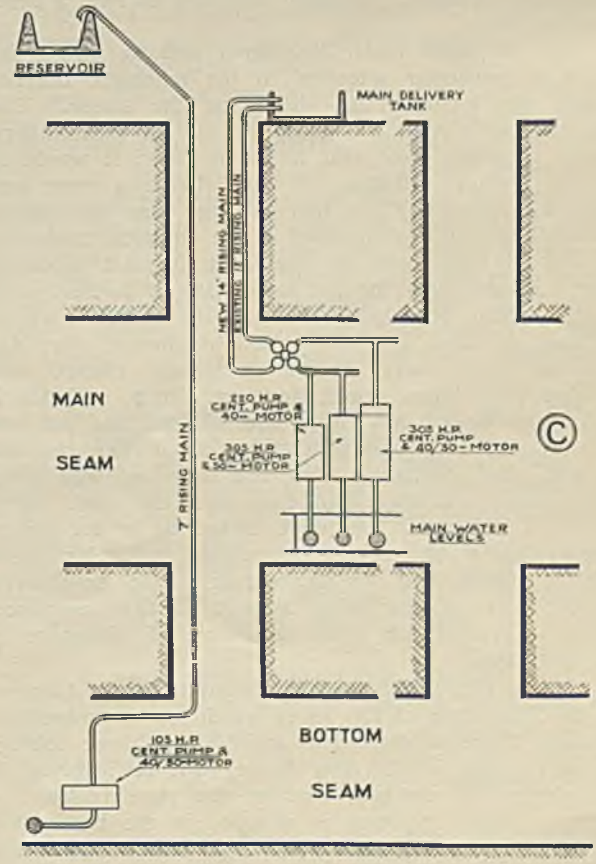


Fig. 18*c*.

assertion that though the changeover procedure with which most of us in this part of the country are now acquainted may not be perfect, it nevertheless is the best procedure that can be devised in the joint interest of the Consumer, the Authorised Undertaker and the Central Electricity Board.

You will observe that the paper comprises Notes for Colliery Engineers; may I remind you that this title has been advisedly chosen and that questions relating to financial aspects of changeover therefore cannot properly be discussed at this meeting. Such matters naturally are for negotiation with Colliery Owners and Agents alone.

Mr. Lambert has mentioned the sensible application of 40/50 cycles interfrequency and dual-frequency (reconnect) motors for anticipatory changeover work and has reminded us of the technical suitability of such machines for these purposes. May I enter a further plea for the general application of these types of motor where additions to Consumer's electrical installations prior to the affording of 50 cycles supplies are contemplated; the same technical considerations apply coupled with the further important consideration that it is not in the National interest, at this juncture, to spend money upon plant the design of which does not fit it for more than a very restricted term of useful service.

Mr. R. W. MANN.—This was an excellent paper wherein the subject was dealt with carefully and in great detail. The paper was of the greater interest due to the fact that it had been given not only by one of the members, but by one of the Branch Committee members. As a member of the Papers Committee, Mr. Mann had some eight or nine years ago asked Mr. Lambert to give them a paper. At that time Mr. Lambert had assured him that it was out of the question. After hearing this paper Mr. Mann could not resist suggesting that there were many other members present who could follow Mr. Lambert's example and offer to read a paper next session.

Of the paper itself, Mr. Mann said he would like to draw particular attention to the schematic diagram which Mr. Lambert had shewn on the screen. This diagram was a sample of those got out for each colliery, copies of which were sent to the colliery; it would be of the greatest assistance if these diagrams were kept up-to-date regularly so that at any time the fullest information could be obtained of the electrical equipment in any district, and an intelligent forecast made of future requirements for the installation of further plant.

It would be appreciated that the actual work as detailed by Mr. Lambert would commence after the manufacturers' share of the frequency change was finished. Mr. Mann would, however, like to add that it was apparent that Mr. Burns and his staff had put into the organisation of this undertaking an enormous amount of work and forethought, but that they can only bring to a logical and successful conclusion the work which they had laid out if they were backed up by the closest co-operation of the colliery engineering staff. Mr. Mann said he thought that Mr. Lambert should not be allowed to go away without being assured of that assistance, which will make the whole procedure of advantage to all concerned.

Mr. A. HEPBURN.—I must congratulate Mr. Lambert on the excellence of the paper which he has submitted. It ought to be of very great assistance to those colliery engineers who, in the near future, will be involved in the process of changing over to the standardised frequency. Ample evidence is afforded in the paper that provided colliery engineers work in close co-operation with the Supply Companies' engineers the results accruing from the change will be most beneficial to both parties. The thorough manner in which the various items of detail have been tabulated leave little doubt that the process of changing over will work as smoothly as one could desire. This of course does not mean that the resident engineer will be free from worry during the transitional period but on the contrary will find scope for all the energy and ingenuity that he may possess. The various cards collected will undoubtedly prove most valuable in future years provided they are carefully stored and kept up-to-date. I venture to suggest that additions to such a record, which the addition of any new plant will entail, ought to be made from time to time as circumstances may require thus forming a comprehensive record of all electrical plant in service at any individual colliery.

Mr. E. B. FORSTER proposed a vote of thanks to Mr. Lambert. Perhaps this had been entrusted to him because he happened to be connected with a coal company who had already received the attentions of Mr. Lambert and his staff. When Mr. Lambert put the slides on the screen and spoke of the various cards, black and red, the thought had flashed through Mr. Forster's mind of the experiences he had had with the routine. The black sheets were recived and they had to fill them in. Of course that took much longer time than did the author's description. After finishing the black sheets, and signing the red sheets and posting them it was found that the black sheets were inclined to be elusive. Mr. Forster was not sure whether he had all his yet—whether they were in the hands of the N.E.S. Coy. or the manufacturers. But, having received the services of Mr. Lambert and his staff of the N.E.S. Coy. he would like to congratulate them all on the way in which they carried through the work, and the fair spirit in which it was conducted. Mr. Lambert was a man who knew his job and one whom it was a pleasure to work with. In his, Mr. Forster's case they had reached the stage where the whole of the plant had been gone through. It had all been scheduled and was on order. Personally, Mr. Forster felt that when they had finished with the frequency change they would be better off than before. They would have a more modern and up-to-date plant. It was, in effect, a re-start from the beginning and he would say that none need look forward with fear to the time of going through the change. He had much pleasure in moving a vote of thanks to Mr. Lambert for the very able and comprehensive paper he had given.

Mr. SIMON seconded the proposition. He, Mr. Simon, was somewhat in the same position as Mr. Hepburn so far as his collieries were concerned. He would venture to make one suggestion: it had occurred to him with regard to the plan of the changeover that it might make things a little easier to have a board with red and black discs which could be turned over so that it would be possible to see exactly what the diagram looked like at each stage. No doubt Mr. Lambert had some scheme in order to get out that schedule which he had read so glibly but which he had acknowledged "took some doing." Mr. Simon hoped that the changeover would take place with the same ease that Mr. Lambert had shewn in reading the paper. He would like to add his personal congratulations for the very able way in which the whole scheme had been organised.

Mr. LAMBERT (in reply) said he would be more than satisfied if he had been able to give any useful assistance to consumers in arriving at speedy decisions with regard to the replacement plant. With reference to the remarks by Mr. Simon it was quite a difficult task to shew the sequence of changeover on a lantern slide but it would be very much easier perhaps if different coloured inks were used to form a plan in sequence so the conditions in the first, second and third week-ends could be seen and the plan arranged in elastic form to close up on the concertina principle.

KENT SUB-BRANCH.

Testing and Certification of the Flame-proof Enclosure of Electrical Apparatus.

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

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

Tests made with inflammable gas, to ascertain whether the enclosure of electrical apparatus is, in fact, effective to prevent the propagation of flame to the surrounding atmosphere, are not by any means a novelty either abroad or in Britain.

In evidence before the Departmental Committee, on the use of Electricity in Mines, which framed the first code of Special Rules in 1903, the late Mr. W. E. Garforth (Sir William Garforth) described experiments that he had made, using town's gas, with various motors and switches, in special testing galleries. He had also experimented with pressure relief devices, such as gauze and tubes of small bore. Mr. Garforth favoured plain metal-to-metal joints and distrusted packing or jointing material.

The late Mr. W. C. Mountain also described before that Committee, similar experiments that he had made independently.

Mr. Sam Mavor, who is still with us, and still well to the fore in all that concerns the safe use of electricity in mines, testified that it was reasonably practicable to design a "flame-tight" coalcutting machine—and to keep it so. He rejected, as illusory, the term "gas-tight."

Some seven years later, before the next Departmental Committee, which sat in 1909-10, and formulated the General Regulations governing the use of electricity in mines, which with minor alterations, are in force to-day, several witnesses discussed flame-tight enclosure, but in this instance reference will only be made to that given by two of them; Mr. H. W. Clothier, who also is still with us, and is a member of the North of England Branch of this Association; and Mr. G. Ralph, also of Newcastle.

Mr. Clothier wanted the Home Office to undertake to test and approve electrical apparatus with a view to raising the standard of quality, in order that greater safety in the use of electricity in mines might ensue. He spoke of "explosion-proof" switch cases having wide metal-to-metal flange joints, suggested a minimum flange width of 1¼ inches, and mentioned rough machining of the joint surface as a means of affording relief of pressure against an internal gas explosion.

Mr. Ralph described experiments with a 30 h.p. enclosed motor, fitted with "plate ventilation," or a ring relief device, as it is called to-day. This device was built up of rings and spacers of armature iron 0.018 inch thick; the radial length of the surface being 50 m.m. (2 inches) and the spaces 0.5 m.m. (0.02 inch), according to the Specification of Dr. Beyling who had carried out experimental and research work in Germany between 1903-05 (using natural firedamp as the test gas). That work was initiated by the Mining Association of Dortmund and the financial responsibility was subsequently assumed by the Westphalian Mining Fund.

Mr. Ralph's experiments were made with town's gas, which was allowed to flow into the enclosure until it made an explosive mixture with the air therein, whereupon it was ignited by a sparking device which was generally set in operation before admitting the gas. Sometimes the explosion was quiet but at intervals it was violent and visible flame issued.

He had also experimented with thicker plates (1/16 inch) and a flange breadth of 3 inches and observed that with this alteration the emission of visible flame was prevented, but as he did not then get any repetition of the violent explosions he was not prepared to pin his faith to the ring relief device in either form. He had been able to ignite a gas jet placed close to the venting device.

He had also experimented with rough machined flanged joints for switch-box enclosures and had found that with a breadth of 1 inch no visible flame issued, but that with a breadth of ⅝ inch visible flame was observable, in the dark.

This witness also, although unassociated with the National Electrical Manufacturers' Association, on whose behalf Mr. Clothier tendered evidence, also favoured Home Office approval of electrical apparatus for collieries, with a view to excluding unsafe equipment. "Absolutely unfit and rotten stuff" were the words used by Mr. Ralph!

It should be pointed out that at that date official approval of flame safety lamps had not been instituted and that such lamps were simply required to be "flame-proof" as we might say to-day, and locked.

The Chairman, now Sir Richard Redmayne, then asked him: "How far do you use the word approval? Do you mean that before any switch, which deviates, however little, from an existing standard, is introduced into a mine, it should be hall-marked, so to speak, by the Home Office, as a fit and proper type?" While the witness in his reply would not go to this length, he maintained his personal preference for Departmental interference as a check upon the competition of cheap and unsatisfactory apparatus.

There this issue rested until in 1922, again at the request of the Manufacturers and with the concurrence of the Mines Department of H.M. Board of Trade; and, it may be permissible to add, under the stimulus of certain paragraphs in the revised edition of the Memorandum on the Electricity Regulations, published in April 1921, wherein the purchaser was advised to seek a guarantee from the seller that the apparatus was in fact flame-proof, the Mining Department of the University of Sheffield undertook to test and, if satisfied, to Certify that electrical enclosures submitted to them, were flame-proof.

First under Professor Douglas Hay, and latterly under Professor I. C. F. Statham, Sheffield University, made type tests of a variety of electrical apparatus and issued Certificates, between August 1922 and April 1931, in favour of some 372 articles, ranging from coalcutting machines to cabin fans.

Now, the author's delving into ancient history stopped at Sir Richard's question, because therein lies the kernal of this matter of Certification, after Type Test, of electrical apparatus purporting to be safe for use in presence of an inflammable atmosphere.

A Type Test, as distinct from an individual test applied to each article, loses much of its value if the model subjected to a type test, and accepted upon the basis of that test, is not truly representative of the bulk.

In biological parlance, if the strain is not homozygous or true breeding, examination of an individual specimen is no safe guide to the characteristics of subsequent generations. There may be reversion to an ancestral type or variation either "per saltum" or "gradatim."

How then are alterations in the design, which may reduce the margin of safety even if they do not introduce actual danger, to be prevented?

Means to that end are, a full description and a detailed working drawing of all that pertains to the flame-proof enclosure, as an essential part of the implied contract between the Manufacturer and the Certifying Authority.

With the best intention, however, errors in manufacture or carelessness in assembly, of the components of a flame-proof enclosure are liable to occur before the apparatus reaches the user; but with modern methods of workshop testing, gauging and checking, such faults can either be eliminated or kept within the limits of safety.

The author forbears to say anything here about the enterprise of the user but is quite alive to the possibilities.

This leads to insistence on the necessity for an ample margin of safety in the permissible dimensions of joint surfaces and other passages through the wall of a flame-proof enclosure and in the designed strength of the enclosure as a whole.

Taking the latter into consideration first, the pressure developed on test can be observed and recorded and, therefore, a comparison can be made with the strength of the enclosure ascertained either by calculation from the known strength and dimensions of the materials or, better still, by actual test, for example by hydraulic pressure.

The only alternative in sight is to use for the test an inflammable gas or vapour that imposes a greater pressure, or a more sudden development of pressure, than that which results from the inflammable gas normally encountered. Where firedamp (methane) is the inflammable gas normally encountered, it is easy to select another inflammable gas that will provide a margin but such a substitution introduces other variants, such as the maximum safe width of the gap between flanges. For example, pentane vapour could be substituted for methane, giving a maximum pressure of, say, 136 lbs. per sq. in. as compared with 107 lbs. per sq. in., for methane but the safe gap width is reduced, and in practice we require that for apparatus intended for use in oil ships or petrol stores, which is tested with pentane, the gap width shall not exceed 0.010 inch; whereas we alow a gap width of 0.020 inch for apparatus tested with methane, within the enclosure.

The rate of development of pressure with methane and with pentane is slightly in favour of pentane as the test gas, i.e., it imposes a rather more sudden stress, but the difference is not sufficient, in itself, to increase materially the presumption in favour of apparatus so tested.

Moreover, one must consider the man in the street or, rather, the man in the mine. Scientific knowledge is not his strong point and it will be more convincing if mining electrical equipment is tested with firedamp and not with some substitute.

Considering now the margin of safety in the permissible dimensions of joints and bearing or spindle clearances, the elaborate research that has been carried out by the Safety in Mines Research Board under the direction of Professor R. V. Wheeler and by other investigators who have given their attention to the scientific aspect of the problem, has shewn that a gap 3/64 inch (0.047 inch) wide between rigid flanges, 1 inch broad, will not pass the flame of any inflammable mixture of firedamp and air at ordinary temperatures, so as to ignite an inflammable mixture of firedamp and air outside the enclosure.

We have accepted the dimension of 1 inch for the breadth of such joints and other comparable passages for flame but we have limited the width of the opening, across the passage, to 0.020 inch, as a maximum because increase in gap width is more dangerous than decrease in flange breadth; or, in other words, because the cross section of the opening is, within limits, of more importance than the length of the path.

We have in this respect, therefore, a margin of safety but it is not a true testing margin, in the engineers' use of the term. We endeavour to apply a testing safety factor by observing whether visible flame or sparks issue from any such openings in the structure while making preliminary or observation tests, i.e., before surrounding the apparatus with an explosive envelope. If visible flame or sparks issue, the apparatus is rejected, although with a few trials no external ignition may result. In this we are following the practice that Professor Statham established at Sheffield.

It will now have been observed that all the earlier testing, to which reference was made at the beginning of this paper, was done with town's gas and as a matter of fact town's gas has been used by several manufacturers who, either regularly or occasionally, have made their own flame-proof tests at their works, mainly for their own information but sometimes for the satisfaction of a customer.

Such enterprise is wholly to be commended and if one merely considers the nature of the gas, it imposes a slightly more severe test than methane does, which makes necessary a short reference to two of the observed characteristics of hydrogen, which is the more important constituent of town's gas from our present point of view. The maximum pressure to be expected with the most explosive mixture of hydrogen and air is not seriously greater than for firedamp, viz., 110 lbs. per sq. in. as compared with 107 lbs. per sq. in., but the rate of development is in marked degree more rapid, comparable figures being 0.008 second for hydrogen and 0.069 second for methane. Brittle structures, therefore, may be unable to resist a hydrogen explosion.

Town's gas is of course so variable in its contents that corresponding data without reference to the analysis of the sample are of little value. The author has figures of 103 lbs. per sq. in. and 0.050 second for a particular sample of town's gas.

The second distinguishing characteristic of hydrogen is the difficulty with which its flame is extinguished, that is to say a gap width that suffices to confine the flame of methane or of pentane on the safe side of the enclosure is useless for hydrogen even when the external or indicating gas is the relatively lazy and inert gas, firedamp.

According to the results of certain tests of which the author has information the safe gap width for hydrogen, using the term "safe" in the laboratory sense, is 0.004 inch, whereas that for pentane is 10 times, and that for methane is 12½ times, as great. Obviously therefore, hydrogen cannot be substituted for methane without imposing severe restrictions upon the design which are unnecessary when firedamp only need be considered under the conditions of use.

Hydrogen, however, is the appropriate gas to use when testing certain classes of apparatus, or for any apparatus that is to be certified as safe for use in the presence of hydrogen or of coal gas. The latter proposition is self-evident and calls for no exposition. The former proposition, however, requires some justification.

What, in short are those classes of apparatus that should be tested with hydrogen? In brief, all oil-immersed apparatus for which a flame-proof enclosure is desired.

When the hydrocarbon oil employed in switchgear, for example, is "cracked" by the electric arc, as when the circuit is broken under load, a bubble of gas results and this gas being hot and lighter than the oil, rises quickly to the surface and may accumulate in any air filled spaces until it forms a highly explosive mixture there. The gas produced in this way, and produced inevitably in every switch each time an arc, however small, is drawn under the oil, consists roughly of 60 per cent. hydrogen and 12 per cent. acetylene with some 6 per cent. of methane, as the only other inflammable ingredient of any consequence.

Hydrogen and acetylene are both more dangerous gases than firedamp and that for more reasons than one. They are both ignitible, or explosive, over a much greater range of concentration than is the case with methane. Roughly, from 3 to 80 per cent. for acetylene and from 6 to 70 per cent. for hydrogen, as compared with 6 to 14 per cent. for methane.

Again, the pressure developed with acetylene is much higher than with either hydrogen or methane, apparently in the region of 132 lbs. per sq. in., and the safe gap is much narrower than for methane but not so narrow as that for hydrogen. However, as hydrogen predominates in the gas derivable from switch oil it suffices to test with hydrogen alone, ignoring the other constituents.

While it is only recently that much attention has been paid to the nature or volume of the gas so formed it has long been known, or suspected by manufacturers of oil switchgear that the occasional violent destruction of an oil switch, in industrial service, was due to a gas explosion and that hydrogen and acetylene were the gases concerned.

The author has assumed, thus far, that all present are aware of the establishment by the Mines Department this year of a Testing Station for flame-proof enclosures of electrical apparatus, at Harpur Hill, near Buxton. The decision to undertake the responsibility of this work and of certifying apparatus, upon the basis of type tests, with which the Mines Department was satisfied, was taken during 1930, and the buildings and plant were completed and ready for beneficial use in May of this present year.

The lantern slides which by the courtesy of the Mines Department, the author is able to shew this evening, and for which he is indebted to Mr. Rainford, give a general idea of the provision that has been made for taking over this important and responsible work which, as already mentioned, was carried on for nearly nine years by the Mining Department of Sheffield University, to whom, and to Professor Statham in particular, the industry is undoubtedly indebted.

The testing officer is Mr. H. Rainford, who for several years acted in that capacity for Sheffield University under the general direction of Professor Statham. It may also be mentioned here that Professor R. V. Wheeler will act in an advisory capacity to the Mines Department upon matters concerned with the testing of apparatus or in connection with work of an experimental nature.

It cannot be too clearly understood that the Mines Department Certificate will not be granted solely upon the results of tests with inflammable gas.

Before apparatus is accepted for test, drawings will be examined and the design of all that pertains to the flame-proof enclosure will come under critical review and, where such guidance is available, principles of construction that have been prescribed in a British Standard, or other equivalent National or Authoritative Specification will be taken into consideration.

Whilst we cannot undertake to vouch for the electrical and mechanical quality of apparatus that we may certify as flame-proof, we cannot ignore that aspect, as to which a declaration of compliance with British Standard Specifications, as to rating and performance, will be considered as a recommendation.

Even then a certificate will not follow automatically if apparatus passes through certain tests without causing an external ignition. The actual examination of the model or the tests may disclose unsuspected defects or weaknesses, or the margin of safety may be found to be too small. While, so far as may be possible, the same standards as to construction, will be required in all parallel instances, that must not close the door to progress. If better, i.e., safer, principles of construction are presently forthcoming they must be allowed to set the pace until they in turn fall out of the running.

That is not to say that there will be no stability or permanence in our requirements or methods of testing for we shall, so far as may be possible, work in association with such semi-public organisations as the British Engineering Standards Association, and it will continue to seek for a solution of each little problem as it arises by agreement upon the merits of the case, with those who by experience and by responsibility are able to speak with some measure of authority with a view to the inclusion of all such agreed requirements in a British Standard Specification.

Nevertheless we shall always be willing to test experimental apparatus in order to provide data for the designer, and in such instances of course, our scrutiny of the design will be relaxed, as no Certificate will be involved.

We may have started somewhat late in the day with official testing of this nature but that is not altogether our loss and so far as the standard of safety applies to the construction of the better class of electrical plant in British Mines this country has nothing to fear and little to learn from a comparison with that produced elsewhere. Please however observe the qualification "the better class of electrical plant."

While the author would not be justified in adopting Mr. Ralph's language to-day to describe colliery electrical equipment—there is room for improvement, but it cannot come without co-operation, some knowledge of the problem and a desire for better plant coupled with willingness and, it must be added, the ability to pay for it.

Discussion.

Mr. COOPER, submitted the following questions:

1. Where tests have been carried out on oil circuit breakers sufficiently to guarantee that they are flame-proof, does this also prove that they are flame-proof when operating at their full rupturing capacity?

2. Is flame-proof gear, where the hot gases are cooled by copper turnings in spring loaded relief vents, as efficiently protected as those having the broad flange with a narrow gap?

3. As the vent in the switchgear allows gas to enter, does it not also allow water and dust to enter?

4. Is it essential that the terminal chamber must be flame-proof?

5. Most coal face apparatus is cast iron: does the author think it possible that welded fabrication will be the future development?

6. With a motor working on overload is it possible that the whole of the metalwork may become so hot

that the cooling effect of the broad flange will be seriously retarded?

7. Understanding that the new flame-proof certificates are issued from London, and presuming that, although they would be the final flame-proof certificates, would the original Sheffield Certificate still be valid?

Mr. BARNEY.—Has the new Testing Station, erected by the Ministry of Mines, and described by Mr. Horsley, entirely superseded the Sheffield University Station?

Mr. DAWSON referred to the matter of damp forming in switchgear, etc., and other plant such as motors on coalcutters, and said he understood that there was a device on the market, in the form of absorbent pads, to take the moisture out.

Mr. HORSLEY, in reply to the several questions by Mr. Cooper, said:

1. I have no information upon which to found an answer, but it is unlikely that the stresses arising from these two causes would attain maximum simultaneously.

2. I do not know how to assess such efficiency. A venting device is either effective to prevent ignition, or it is not. If reliability is meant, Mr. Cooper is as competent to form an opinion as I am.

3. I agree. This is an argument against such vents, but vents are not a necessary concomitant of flame-proof enclosure.

4. This depends on how much importance is to be attached to the attainment of safety in all parts of the apparatus. It would certainly be wise to make the terminal box flame-proof.

5. Welded (fabricated) structures are being used increasingly for switch boxes and such apparatus.

6. This is hardly possible as the temperature of the flame is so high, compared with any possible working temperature of the apparatus that the rise in temperature of the latter is relatively negligible.

7. We shall consider its case upon its merits. If we are satisfied with the design and with the tests upon which the certificate was based we shall be prepared to give our covering certificate where it is asked for.

In answer to Mr. Barney, Mr. Horsley said that the Sheffield University Station had ceased to certify commercial apparatus as flame-proof.

Mr. Horsley said he had no knowledge of the device mentioned by Mr. Dawson. A remedy for consideration is free circulation of air, but that was hardly practicable for coal face machinery because it involved the free admission of dirt. Mr. Horsley said he had not heard that condensation was in fact troublesome in coalcutting machines, which for many years had been constructed without vents.

WEST OF SCOTLAND BRANCH.

ANNUAL DINNER.

The Annual Reunion Dinner of the Branch was held in the Grosvenor Restaurant, Glasgow, on Saturday, 5th December, 1931.

Mr. Arthur Dixon, B.Sc., President of the Branch, occupied the Chair. Mr. Dixon was accompanied by the following guests:

Mr. Simon P. Hodge, Managing Director of Manor Powis Coal Co., Ltd.; Mr. F. Beckett, Senior Vice-President of the Association; Mr. Mark Brand, President of the Mining Institute of Scotland; Mr. W. A. Dexter, Director of Mirrlees Watson Co., Ltd.; Mr. D. Archibald, President of the Colliery Managers' Association (Scottish Branch); Mr. Gerrard, Corporation of Glasgow Transport Department; Mr. D. A. MacCallum, Secretary of the West of Scotland Iron and Steel Institute; Mr. James Garven, President of the Ayrshire Sub-Branch; Prof. G. W. O. Howe, President of Institution of Electrical Engineers (Scottish Centre); Mr. D. J. Barr, Managing Director of Wilsons & Clyde Coal Co., Ltd., and Robert Addie & Sons Collieries' Ltd.; Mr. R. M. Russell, of Robert M. Russell Ltd.; Mr. George Herbert, Managing Director of The Craigpark Electric Cable Co., Ltd.; Mr. John George, Secretary of Colliery Managers' Association (Scottish Branch); Mr. W. H. Napier, General Manager of John Watson Ltd.; Mr. J. C. MacCullum, Secretary of the Ayrshire Sub-Branch.

The following Past Presidents of the Branch were also present: Messrs. F. Anslow, H. A. McGuffie, D. Landale Frew, C. E. Hart, Alex. Anderson, A. B. Muirhead, David Martin, and G. N. Holmes.

Mr. SIMON P. HODGE, proposing the toast of "The Association", said that the coal trade was suffering to-day as much from a surfeit of legislation as from competition among themselves. The Act of 1930 had not brought them one iota of benefit. Under the Act it was possible, in his view, to have established some system of central selling, but coalowners, and especially the most influential coalowners, were very individualistic, and so the endeavour to get the powers under the Act of selling coal centrally and thereby obviating the cut-throat competition, which was the bugbear of the trade had come to nothing. He believed that this combination in selling was necessary to the salvation of the industry, but it was idle to deny that there was no immediate prospect of such a development in view of the present attitude in influential circles in the coal trade.

Mr. FRANK BECKETT, in responding to the toast, said that the Association was formed about 22 years ago because it was felt that there were not the facilities in any of the existing technical associations for adequate discussion of the special problems which arose in connection with the application of electricity to mining. It was a common occurrence 25 years ago to hear the expression that anything was good enough to put in a pit. Now that was all changed, and nothing but the best would do.

The opportunities offered by the Association for designer, consulting engineer, colliery manager and colliery electrician to get together and exchange ideas and experience had, he maintained, resulted in the high standard attained in the design and maintenance of electrical plant as used in mines. Further, he was of the opinion that the improvement in the design of much of the industrial plant today was due to the high standard set by the plant designed for mining services. He felt that the Association could take a good deal of credit for the improvement.

Dealing with the question of the training of colliery electricians, Mr. Beckett stated that this was one of the primary objects which the Association kept before them. The Association Examinations, which are of a very high standard, rendered very useful service to the industry. Four hundred and forty-one certificates had been awarded to successful candidates; whilst the degree of proficiency expected from the candidates was such that the possession of an Honours or a First-Class Ordinary Certificate, was a guarantee that the holder had such a sufficiently specialised knowledge of the application of electricity to mining as would enable him to take charge of the electrical installation of a group of collieries.

Mr. Beckett reminded his hearers that the Home Office were considering the question of the qualifications and certification of colliery officials, including engineers, and expressed the opinion that when the time came for the Home Office to issue new regulations on this point the possession of the Association's Certificate should be of considerable value to the holder.

Consideration of the great increase in the amount of electrical plant installed in the mines today, and the more complicated nature of much of the apparatus, especially near the coal face, emphasised the necessity of having properly trained men to instal and maintain it: the time was past when it could be entrusted to a "handy man".

Mr. Beckett also drew attention to the excellent Journal of the Association, which he said was much the best of any published by any other Association.

Mr. A. F. STEVENSON submitted the toast of "Our Guests".

Professor G. W. O. HOWE, replying, said that the present was a time of very great crises. For the first time in our history we were under the humiliation as a nation of not being able to pay 20s. in the £1. During the past few years we had been living in a fool's paradise, and we now knew some of the consequences. He was afraid that we had yet more to learn. There seemed to be something radically wrong with the old economic system of the world. When Nature was especially bountiful the effect was the opposite of what might be supposed. A bumper wheat crop in America was apparently regarded not as an occasion for harvest festivals but as a calamity. As an electrical engineer he had not, like the politician, an infallible cure to offer, but he thought that there was at least a partial remedy in the practice of hard work.

Presentation of Prizes.

Mr. ARTHUR DIXON, President of the Branch, in presenting the prizes reminded the members that the Association as a National Body presented three prizes annually for the best papers submitted by colliery electricians. While the West of Scotland Branch might not have attained outstanding success in the Examinations, the members were usually well placed in the prize-list for papers. He reminded them that last year the first and joint-third prizes came to this Branch. This year again the Branch was to the fore in the person of Mr. Robert Wilson, who had been awarded the Association's First Prize value Eight Guineas.

In the Branch too it was customary to present two prizes annually for the best papers, and these this year had been awarded to Messrs. Lightbody and Wilson. At first sight, it might appear anomalous that Mr. Wilson should receive the Association's First Prize while he should only be awarded the Branch Second Prize, but he would explain that Mr. Lightbody's paper had been published in the Journal too late to be included in the annual review of papers for the National Prizes, but that it would come up for consideration in that respect next session.

Mr. Wilson had already received his Association Prize direct, and Mr. Lightbody had also received his Branch Prize, but he (Mr. Dixon) had much pleasure in presenting Mr. Wilson with the prize awarded him by the Branch. He trusted that the success of these gentlemen, both Nationally and in the Branch, would encourage other colliery electricians to come forward and, in the form of papers, give the Association the benefits of their valuable experiences.

Mr. JAMES R. LAIRD proposed a vote of thanks to the artists, Messrs. Burnside, Watson, Brown and Cross.

Mr. A. B. MUIRHEAD submitted a vote of thanks to the Chairman.

Visit to Glasgow Corporation Transport Works.

Prior to the dinner, a visit was paid to the Corporation of Glasgow Transport Department's Coplawhill Works, when over 50 members took part. The visitors were received by Mr. Gerrard and his assistants, and were shewn over the spacious and well-equipped works. At the conclusion of the visit, Mr. Arthur Dixon, Branch President, thanked the Corporation for their kindness in making the visit possible.

YORKSHIRE BRANCH.

Visit to the Brookhouse Colliery.

By kind invitation of the Sheffield Coal Company and Mr. H. Watson Smith, some fifty members of the Yorkshire Branch were privileged to visit the Brook-

Fig. 1.—Members of the Yorkshire Branch at the Brookhouse Colliery.

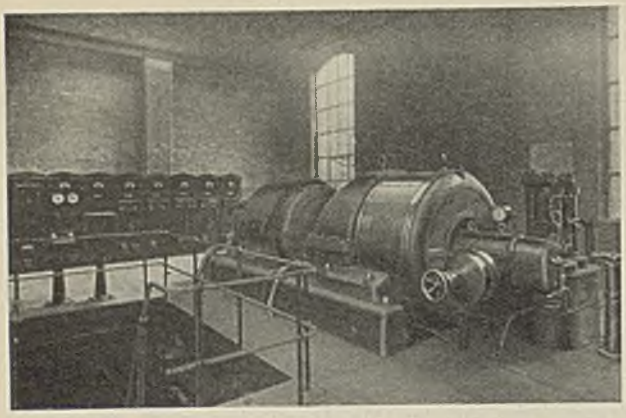


Fig. 2.—Interior of the Power House, shewing 2500 *k.v.a. Turbo-Alternator* (3300 *volts* 50 *cycles* 3000 *r.p.m.) and Truck Cubicle Switchboard.*

house Colliery on 5th July last. The party were entertained to tea by the Company. Mr. Stafford proposed, and Mr. Higgins seconded, a very hearty vote of thanks to the Sheffield Coal Company, to Major Gainsford and Mr. Watson Smith, as well as to the staff who had all combined to make the visit so thoroughly interesting and enjoyable. Major Gainsford and Mr. Watson Smith suitably acknowledged the thanks of the visitors.

The Brookhouse Colliery, which is the latest development of the Sheffield Coal Co., at Beighton, near Sheffield, comprises a new colliery, a new by-product coking installation, and a new central steam and electric power generating plant. The Company possesses three other collieries in the same area, namely, Aston, Beighton, and Birley East. The new colliery which is being planned for a weekly output of 15,000 tons, will include such equipment as an electric winding engine, hydraulic decking arrangements, and screening and coal washing plants. The sinking of the 18 ft. diameter shaft has been completed, and when fully equipped the colliery will be representative of the most modern mining practice.

The electrification scheme is of an unusually comprehensive character, the electric system being linked with the Company's other collieries referred to above. The new equipment includes, in addition to the power house plant, a Ward-Leonard controlled winding engine,

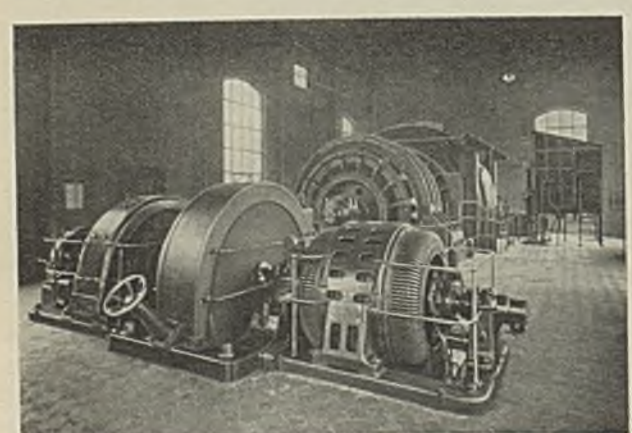


Fig. 3.—Interior of the Winding Engine House, with 1150/2700 *h.p. Electric Winder* 43.5 *r.p.m., and Ward-Leonard Motor-Generator.*

transformers for general distribution purposes, motors for driving the coke handling and screening plant, etc., etc. The contract for the whole of this equipment was placed with the General Electric Co., Ltd., the electrical plant and apparatus being manufactured at Witton, Birmingham, and the steam turbine and mechanical parts of the winders at the Fraser & Chalmers Works, Erith. The coke handling and screening plant was also manufactured by Fraser & Chalmers (in accordance with the Robins system) as sub-contractors to Simon Carves Ltd., who were responsible for the new coke oven plant installed at the colliery.

Steam for the coke ovens and turbine is supplied by two 30,000 to 40,000 lbs. per hour multiple drum boilers fired by pulverised fuel; provision has been made for firing these boilers with surplus coke oven gas, either alone or in conjunction with pulverised fuel.

Power House.

The electric power house (Fig. 2) is grouped with the main power and powdered fuel boiler plant for the colliery and coke ovens. The main generating unit is a turbo-alternator of the direct coupled type, rated for a maximum output of 2500 k.v.a. when running at 3000 r.p.m. on a 3300 volt three-phase 50 cycle circuit. The turbine is of the high pressure multi-stage impulse type working at a steam pressure of 200 lbs. per sq. in. at 200 degs. F. superheat and 28 ins. vacuum. The set is arranged for working in parallel with existing power plant at the Beighton and Birley East collieries.

The main switchboard in the power house is of the truck type and consists of eight panels. The first is equipped with a Tirrel regulator, while the others control circuits as follows: (2) the turbo-alternator, (3) the high tension side of a 50 k.v.a. transformer which supplies station auxiliaries, (4 and 5) two 1000 k.w. incoming feeders from the other collieries, (6 and 7) two outgoing feeders to the winding house, (8) the high tension side of a 550 k.v.a. transformer.

Winding Engine.

The winding engine with its control gear is housed in a well-proportiond brick building, situated about 600 yards from the power house. The general arrangement of the plant is clearly shewn in Figs. 3 and 4. The switchboard in the winding house is also a truck cubicle board. Its five panels control respectively (1) the Ward-Leonard motor-generator set; (2) the high tension side of a 20-k.v.a. transformer supplying the air compressor and other auxiliary motors; (3 and 4) the two feeders from the power house, referred to in the last paragraph, and (5) the high tension side of a 550 k.v.a. transformer. In addition, a pedestal drawout oil-immersed switch unit is connected to the board, and supplies the Aston Colliery. The equipment of the cubicles comprising both the boards referred to (with the exception of that in which the Tirrel regulator is mounted) consists of a suitably rated oil circuit breaker with appropriate protective gear and necessary instruments.

The duty of the winding plant is to raise a net load of 15,676 lbs. of coal from a depth of 1350 feet with an output of 196 tons per hour. The winding drum is directly coupled to the driving motor, which is a direct current machine rated at 1150 h.p. to 2700 h.p. with a speed of 43.5 r.p.m. The motor is supplied from the direct current generator of the flywheel motor generator set. This set (shewn in the foreground of Fig. 3) consists of an 800 k.w. direct current generator of the open compensated type driven by a 900 h.p. induction motor supplied from the 3300 volt mains. A smaller exciter is also direct coupled to the set. The normal speed of the set is 1000 r.p.m., and at this speed the energy stored in the flywheel at full speed is 45,000 h.p. secs. The flywheel gives out the energy required for the peak loads with a speed reduction of 20 per cent. i.e., to 800 r.p.m. This is effected by a liquid slip regulator in the rotor of the induction motor, which is actuated by a torque motor energised through a current transformer on the stator circuit. This slip regulator is designed to act as a starter for the motor generator set.

The flywheel is mounted on its own self-contained bearings and bed-plate, and arranged between the motor and generator. It is of a built-up type, the rim forgings being separate from the web. This construction considerably relieves the stresses set up in the flywheel. Pressure lubrication has been provided for the flywheel bearings, the oil being supplied from a special pump. At starting, the pump is electrically driven but when running the pump is belt driven from the main shaft. An alarm signal is given should the supply fail.

In the design of the winding engine every care was taken to ensure maximum efficiency without sacrificing simplicity of control. The distribution of the rope on the drum was determined with a view to making the power demand as even as possible.

The winding drum, Fig. 5, has a small diameter of 11 ft. and a large diameter of 17 ft. 6 ins. with three live coils on the smaller diameter, five on the cone and 18.6 on the large diameter. It is constructed with cheeks of cast iron made in halves, the rope tread being machined. The cone part has also been made in cast iron halves with rope grooves cast in. These rope grooves are arranged to lead very smoothly from the small diameter to the large diameter to prevent shock on the rope. The large diameter is constructed of mild steel plates, grooved for the rope and machined at the points where they are bolted from the cones. Internally, these plates are stiffened with rings constructed from mild steel sections. These rings add considerably to the strength of the drum.

The motor is carried on its own self-contained bed-plate, the outer drum bearing being carried on a sole plate. The bearings are of the two part self-aligning ring oiling type, the shells being lined with anti-friction metal. Oil catchers are provided on the bearings and, in conjunction with oil throwers turned with the shaft, prevent the escape of oil from the bearings.

The brakes are of the conventional straight post type operated from an air brake engine controlled on the Iversen principle. The principle of this engine is that the air is supplied through a variable pressure reducing valve, which is controlled from the operator's lever to give the variation in pressure. It is so arranged that the air pressure in the brake engine cylinder corresponds exactly to the position of the operator's lever; the brake force is therefore independent of the wear on the brake blocks.

The electrical control scheme may be studied by reference to Fig. 6 which gives a diagram of connections from the truck cubicle board in the winding engine house to the Ward-Leonard flywheel motor generator set, driving motor, and auxiliariary motors, and indicates protective apparatus, measuring instruments, etc.

The speed control of the winder is effected by a reversing controller (shewn to the extreme left of the diagram) in the field of the main generator. It is situated under the driving platform and is actuated by the usual hand lever. The acceleration and deceleration

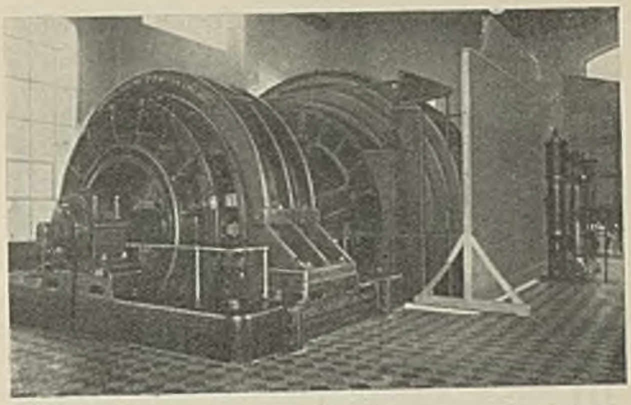


Fig. 4.—The 1150/2700 h.p. Electric Winding Engine.

of the winder is controlled by cams geared to the drum shaft and arranged to act upon the driver's hand lever gear.

The supply for the fields of the generator and motor is derived from the exciter which is direct coupled to the motor generator set. An emergency stop switch, mounted at the driving platform, is arranged to trip the main contactor in the exciter circuit, and this cuts off all power excitation from the winder, at the same time putting on the brake. This exciter contactor, together with the brake and "suicide" contactors and the automatic voltage regulator are mounted in a special cubicle which also contains the exciter voltmeter and field regulator. As the d.c. circuit is always closed it is necessary to provide "suicide" contactors to prevent the residual magnetism in the generator field system from building up sufficient volts to cause heavy circulating currents in the stationary motor armature. These contactors are always in the "suicide" position when the control lever is in the "off" position, and only move to the running position when the preceding operations have taken place in correct sequence. When the controller is in the "off" position an economy resistance is introduced into the motor field to cut down standing losses.

As regards safety devices, the most stringent requirements are met. The winder has the usual limit switches, which are opened upon excessive travel of the cages: the exciter and brake contactor are tripped bringing the winder to rest by means of the emergency brake set, with the "suicide" connection made.

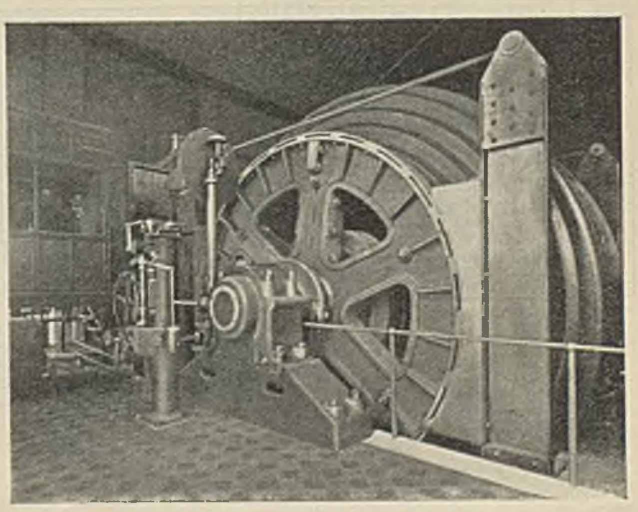


Fig. 5.—The Winding Drum: also shewing part of the control cabin.

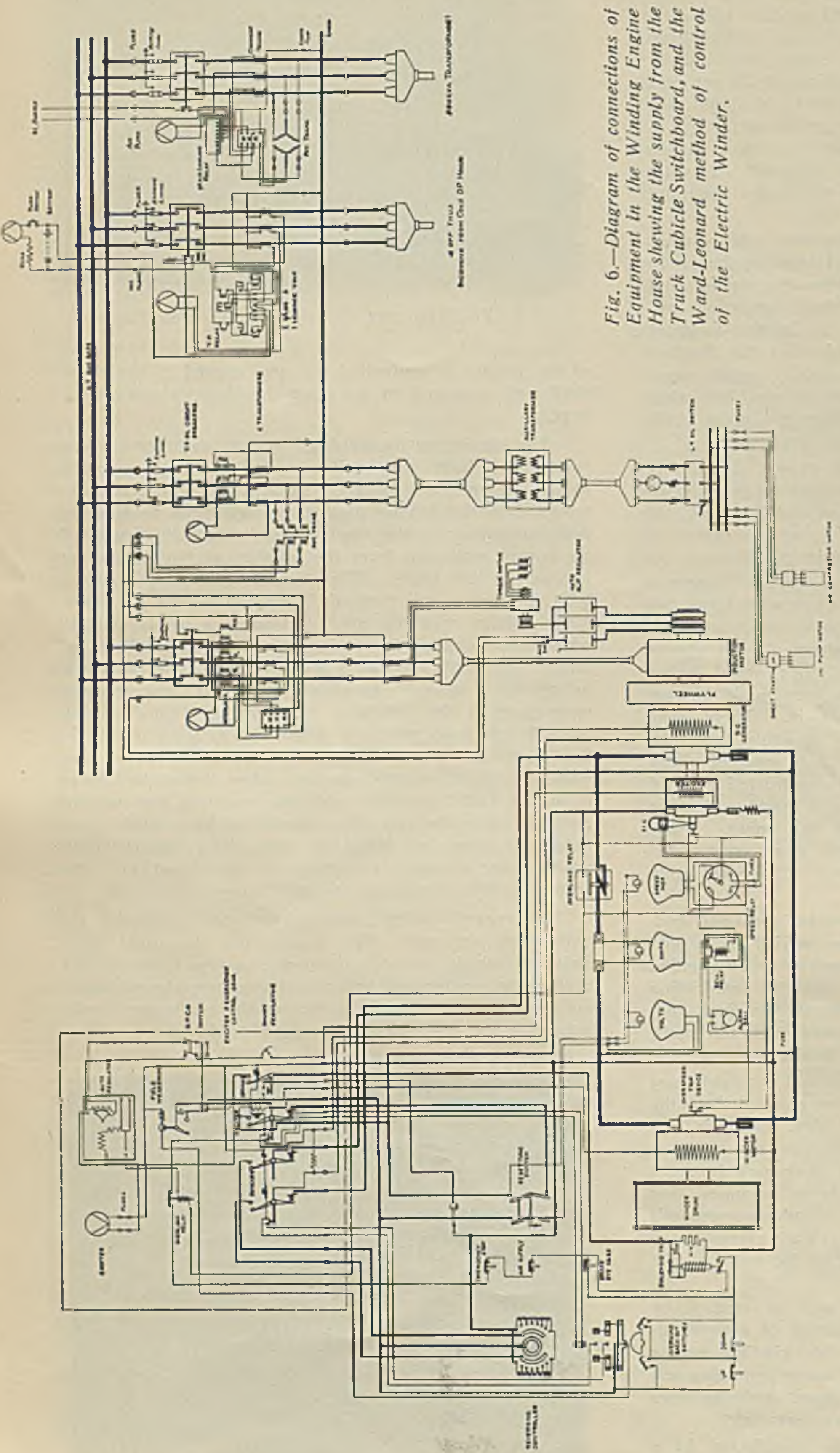


Fig. 6.—Diagram of connections of Equipment in the Winding Engine House shewing the supply from the Truck Cubicle Switchboard, and the Ward-Leonard method of control of the Electric Winder.

To ensure a quick suppression of the machine fields on tripping of the excitation contactor, the latter, when de-energised, short circuits the exciter through a low resistance and so quickly reduces the exciter field current. After an over-wind, the corresponding back-out switch on the controller must be closed before power can be obtained to back out of the over-wind: this switch is automatically re-opened on the first motion of the controller in the direction of the over-wind. As the exciter is shorted through a low resistance, the exciter will not "build up" until this short circuit has been removed by operating the spring-biassed resetting switch. This removes the short circuit until the exciter builds up and closes the exciter contactor again, this being indicated by the lighting of a pilot lamp.

In addition to the emergency stop switch and over-wind switches already mentioned, the following safety features act upon the exciter contactor either directly or through the medium of an auxiliary tripping relay:

(1) A brake by-pass switch which ensures that the driver's brake must be on before the emergency brake can be lifted.

(2) Air pressure relay in brake system.

(3) Winder overspeed switch.

(4) Motor generator overspeed switch.

(5) Main overload relay.

(6) A speed relay, in conjunction with the magneto-generator which supplies the driver's speed indicator, is arranged to energise a relay which rings a bell in the event of the winder's speed rising or falling outside certain limits at any point during the wind.

Reference should be made to a new type of over winding device which has been installed. This device incorporates the new feature of the "Whitmore" overwind which is known as the "landing zone controller," and gives protection against approaching the bank level at too fast a speed. The principle of operation is that the speed of the winder must conform to a predetermined value, which is fixed by the rate of fall of a plunger in a hydraulic cylinder. The rate of fall of the plunger gradually decreases to zero and if the winder does not decrease at the same rate a trip operates the emergency gear.

Fig. 7.—A view of the Coke Ovens and Coke Wharf, shewing point of delivery to belt conveyor.

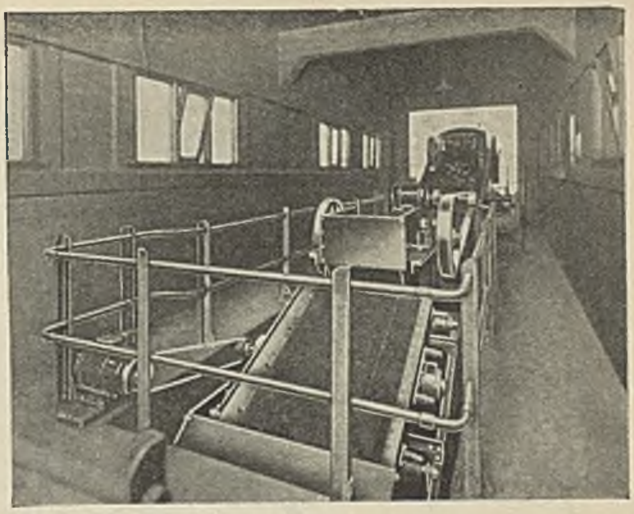


Fig. 8.—Vibrating Screens in the secondary screening house.

The operator's platform (Fig. 5) is raised above the floor level and is enclosed with woodwork to form a cabin, the front being glazed full length. All instruments, pressure gauges and speed indicators are arranged inside the cabin.

Coke Handling and Screening Plant.

Coke is pushed from the ovens on to a hot coke car, being quenched and then discharged on to a coke wharf from which it is delivered through a series of hinged finger gates on to a belt conveyor arranged alongside the wharf, and ultimately delivered into wagons and classification bins *via* primary and secondary screening stations.

The aggregate capacity of the plant is at the rate of 50 tons per hour, the maximum size of coke dealt with being from 12 ins. to 14 ins. and ranging down to smalls.

The wharf conveyor is arranged in a suitable position in regard to the lip of the coke wharf. The finger gates, nineteen in number, are operated from a platform placed above the conveyor and opposite to the wharf in such a position that the operator has a full view of the distribution of coke on the wharf and is able easily to regulate the flow of coke on to the belt. It also enables him to detect any hot spots which require additional quenching before the coke is allowed to flow on to the belt (Fig. 7).

This wharf conveyor carries the quenched coke up an incline into the top floor of the primary screen house where it is delivered over a rotary grizzly screen which separates all under 2½ ins.; the overs are delivered on to a cross conveyor and boom loading conveyor direct into the trucks.

The throughs from the rotary grizzly flow into a hopper underneath, whence they are delivered on to a belt conveyor which elevates and delivers the small coke into a secondary screening house where it is further sub-divided into four distinct classifications and delivered into separate bins by means of two vibrating screens (Fig. 8).

The classifications into which the small coke is divided are ¾ in., 1½ ins., 2½ ins.; ⅜ in., ¾ in.; and 0. ⅜ in. These are discharged into wagons underneath, as required, through suitably operated radial gates fixed to the outlets of the bins.

Arranged in the primary screen house under the head of the wharf conveyor is a rotary coke cutter, capable of cutting coke at the rate of 30 tons per hour and reducing from a maximum of 12 ins. down to 1½ ins. Coke from the wharf conveyor may be by-passed to this coke cutter by removing one or more adjustable plates, which are arranged between the head of the conveyor and the rotary grizzly. These plates allow various capacities up to a maximum of 30 tons per hour to be fed to the cutter. The coke which has been passed through the cutter is delivered on to the small coke conveyor and carried to the secondary screening plant in the manner as described above in the case of the throughs from the grizzly.

The plant throughout is electrically driven, the motors (of the frame cooled type) and the motor control gear being all of G.E.C. manufacture. Should any portion of the plant break down the operator can bring the remainder of the plant automatically to rest by the operation of a push button.

The conveyors and screens are all mounted and carried on steel framework provided with adequate walkways, stairs, ladders and access platforms. The screen houses are arranged over the centres of the railway tracks in such a manner that trucks can be run through between the columns supporting the buildings and shunted into position for filling from the various discharge points.

LONDON BRANCH.

Starting and Speed Control of Squirrel Cage Motors.

J. R. WALTON.

(*Paper read 1st December,* 1931).

The modern polyphase squirrel cage motor is a remarkably fine product. With its practically indestructible rotor and absence of rubbing contacts it requires a minimum of attention and maintenance. Its use in the past has been limited, mainly for two causes: (a) high starting current, and (b) absence of speed control.

High Starting Current.

The older type of squirrel cage motor could only develop full load torque from standstill if it were switched directly across the supply mains, in which case it passed from 4 to 8 times full load current. This high starting current was in many cases objectionable owing to the disturbance it caused to the supply voltage, and any attempt to reduce it by the use of an

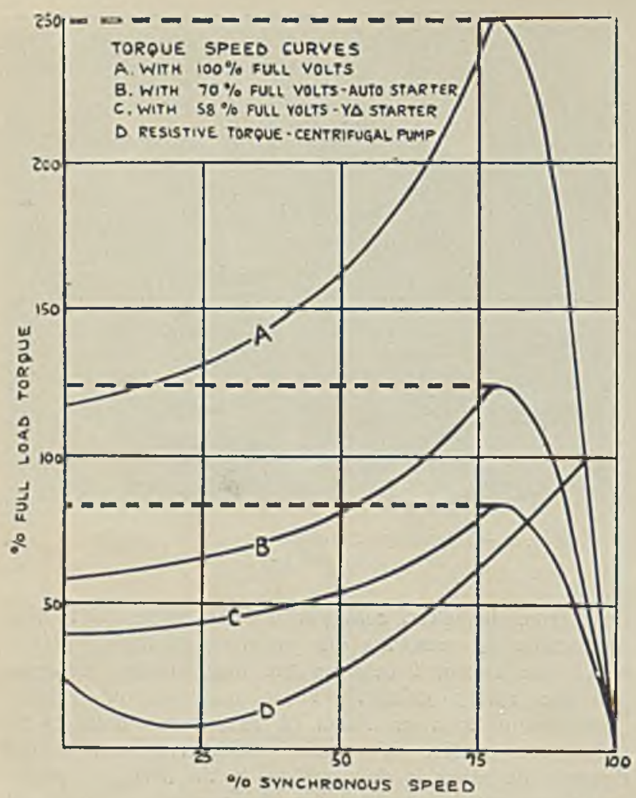


Fig. 1.

Auto-transformer starter, a Rheostatic starter, or a Star Delta starter, reduced the starting torque to too low a value in many instances. With the advent of the high torque machines capable of developing about twice full load torque from standstill, coupled with the improvement of distribution systems the situation has improved considerably and many machines which were hitherto driven by slipring motors, either on account of the high starting torque required or the necessity to restrict the starting current can now be equipped with the squirrel cage machines.

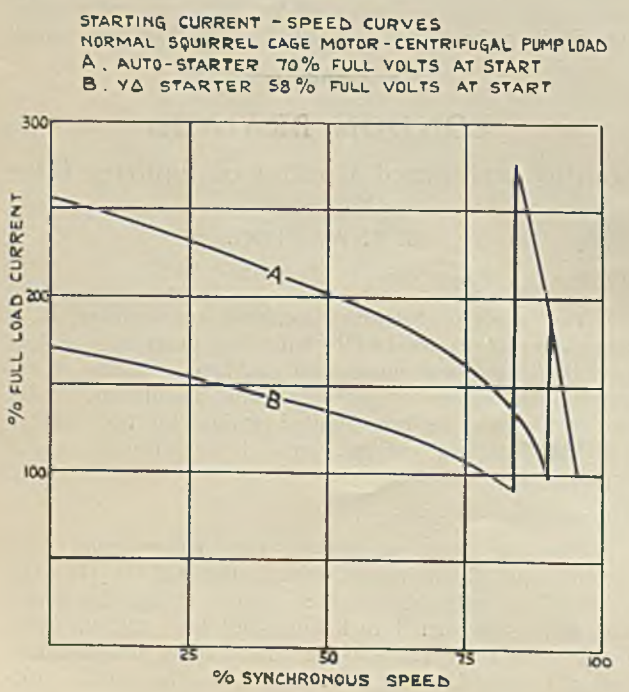


Fig. 2.

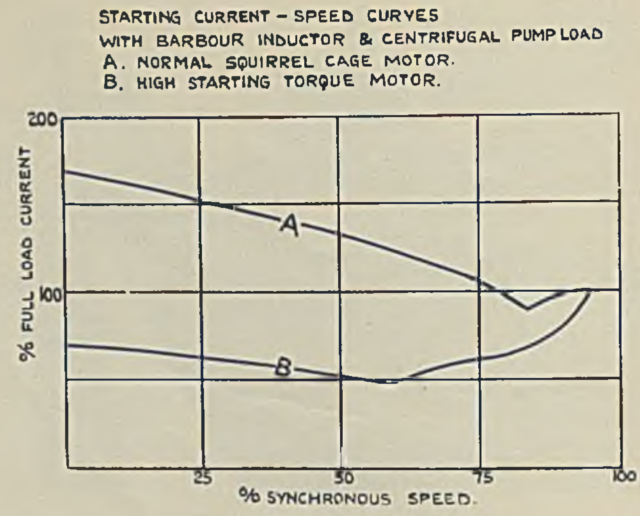


Fig. 3.

There has however remained the fact that considerable rushes of current are unavoidable—take the case of a high torque motor on a duty where normally full load torque at starting is required: this will mean applying about 70% to 75% of full voltage to the motor—probably the torque produced by the star connection of a delta wound motor will not be quite enough, and an auto transformer must be employed. Such a motor very likely has a short circuit current of 6 times full load (8 to 10 times is not unknown in large motors). Then the motor current at the start is $4\frac{1}{2}$ times full load, and the line current just over 3 times full load. This is a heavy kick to come on suddenly: but suppose occasionally just a little more torque is required. There is then no alternative but to switch the motor direct on the line, and both motor current and line current in the case assumed will be 6 times full load.

This may be considered an extreme case—but take even that of starting a centrifugal pump, which for a slipring motor is quite a light starting duty.

The torque needed to get the motor and pump away from standstill is quite low, but this is not true of the accelerating torque.

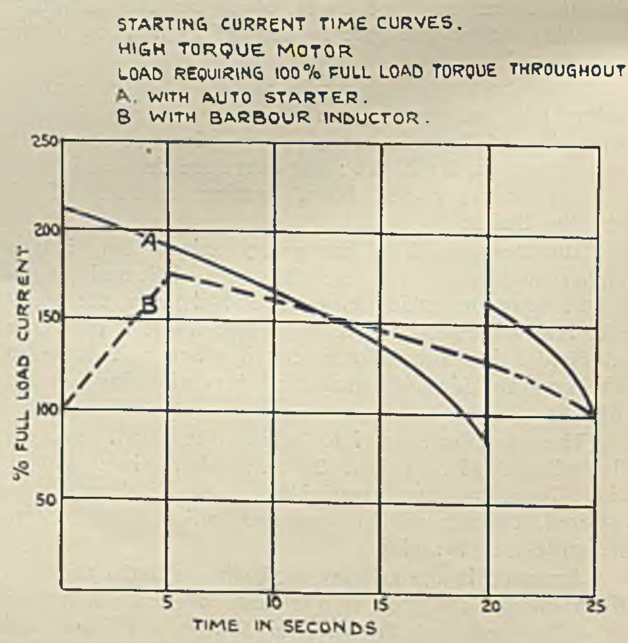


Fig. 4.

In Fig. 1, curve D shews the resistive torque of a centrifugal load—initially only a comparatively small effort is required to overcome the static friction of the machine, but as the speed increases the resistive torque curve rises. If the starting current is reduced by applying a reduced voltage to the motor, a point will be reached where the motor torque curve and the resistive torque curve intersect, and it will not be possible for the motor to accelerate beyond this point unless the voltage is raised, i.e. the starter is switched to the "full on" position. This applies not only to star delta starting, but also to auto transformer starting, unless a very high transformer tapping is used. Unfortunately the use of a high tapping reduces the transformer effect, and brings the line current very nearly up to the value of the motor current.

Curves B and C shew approximately what accelerating torque can be obtained from the use of a 70% auto transformer and a star delta starter respectively, whilst Curve A shews the maximum torque available if the motor is switched directly on to the supply mains.

Fig. 2 gives an idea of the current during the starting period, and shews the current kicks which take place on switching into the running position. It will be seen that these are very considerable, and it is worth noting that although in the case drawn the final peak with the auto transformer is less than the initial current, this would not be so if a lower voltage tapping were employed—it is not as fully realised as it should be that an auto transformer starter does not necessarily keep the starting current down but on the contrary very heavy current peaks may occur when switching to the "full on" position.

If a high torque motor is used (see dotted lines, Fig. 1) much more torque is available at standstill, and while running up to about two-thirds speed, but the kick on changing over to the running position is in no way decreased.

This problem may not be very serious in the case of small motors—it is common practice, of course, to switch coalcutter and other motors direct on to the supply and no great harm results, though the practice must tend to produce a depreciative effect on the windings and on the mechanical equipment. But in the case of larger motors, and particularly if wound for high tension, and subject, therefore, to special insulating difficulties, the disadvantages from the motor point of view are considerable, and in addition the sudden rush of current becomes a nuisance from the point of view of the supply.

Fig. 3 shews the ampere speed curves for a start against the same load, using a Barbour Inductor, and (a) a standard squirrel cage motor; and (b) a high torque squirrel cage motor.

An explanation of the Barbour Inductor will be given later—it will be sufficient at this point to say it is a variable ratio auto transformer enabling the volts applied to the motor to be varied gradually from a predetermined minimum up to full volts.

In the case of both types of motor the kick on switching over to the "full on" position is practically eliminated, with the standard motor the current at the first start can be kept down to what is actually needed to get moving from rest (instead of being kept rather higher so as to minimise the second kick) but is still considerable.

With the high torque motor no undue current is needed at any time.

In addition, in both cases, there is no need to supply a margin to take account of the higher torque that may be required occasionally—owing say, to a little grit in the pump—or to the oil in the bearings being cold. Should the torque required be higher than normal, it is only necessary to turn the inductor so as to bring up the volts and amperes, and so the torque, to the figures actually necessary.

The starting of a centrifugal pump has been dealt with at length, because the initial torque required is low, and it might therefore be thought an easy application for a squirrel cage motor. Although it should be remembered that a considerable inertia load is present in some cases, requiring an appreciable breakaway torque. On a duty requiring full load torque from standstill the advantages of using a Barbour Inductor are still greater—the current at switching on can be limited to any desired values—this can be brought up smoothly to the exact figure necessary for getting a start—and the kick on switching over to the "full on" position is negligible.

Comparative curves of High Torque motor starting against a load requiring full load torque throughout.

(a) with ordinary auto transformer. } Fig. 4.
(b) with Barbour Inductor. }

Speed Control.

The other drawback to the use of the squirrel cage motor has been the absence of any convenient means of speed control. The methods available are:

(1) Pole changing. When two definite speeds are required these can be obtained either by providing the motor with two separate stator windings or by making arrangements whereby the one set of windings can be grouped in two different ways. It is possible to provide more than two speeds but the gear becomes very complicated.

(2) Frequency. The speed of the motor can be varied by varying the frequency of the supply system but there are only a few applications where this is possible.

(3) The speed can be regulated to some extent by the insertion of resistance in the stator circuit, but this is a very uneconomical proceeding owing to the rheostatic losses involved.

(4) Reactance Control can be employed for a limited amount of speed variation thus avoiding most of the rheostatic losses, but causing the power factor of the circuit to be very low.

(5) The speed can be changed by voltage control and it is with this aspect of the problem that it is proposed to deal with at the moment.

The torque exerted by a squirrel cage motor is approximately proportional to the product of the magnetic flux and the current flowing in the rotor and as the flux is proportional to the stator voltage it will be seen that if the stator voltage is reduced the rotor current must increase if the motor is to develop the same torque. The slip or difference between synchronous speed and actual running speed varies with the rotor current so that a reduction in the stator voltage produces a reduction in running speed and an increase in voltage correspondingly causes an increase in running speed up to the synchronous speed of the machine. If, therefor, some convenient means of controlling the voltage is available the speed of a suitable squirrel cage motor can be controlled.

This is of considerable importance to mining electrical engineers all of whom would very much rather employ a squirrel cage motor than one having slip-rings and brush gear. Amongst the drives in which they are interested are haulages, fans and pumps.

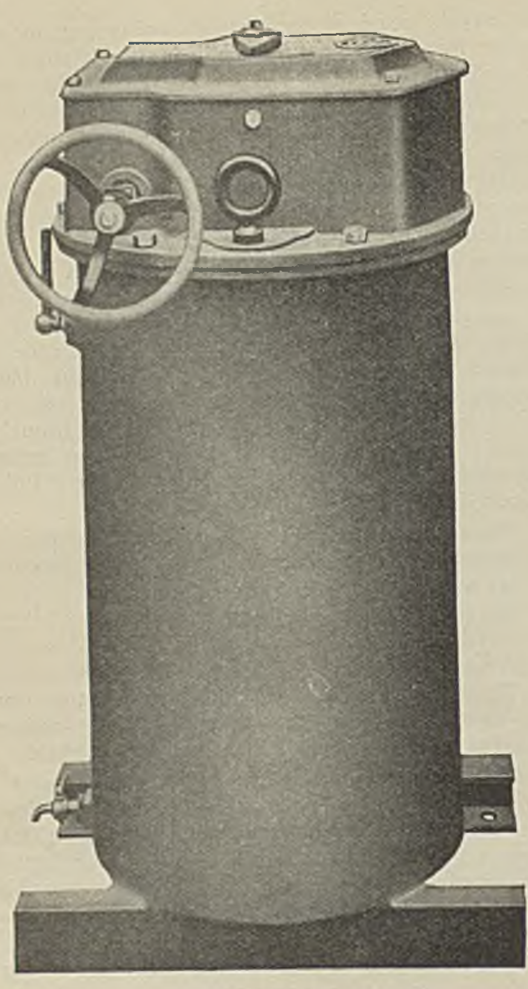


Fig. 5.

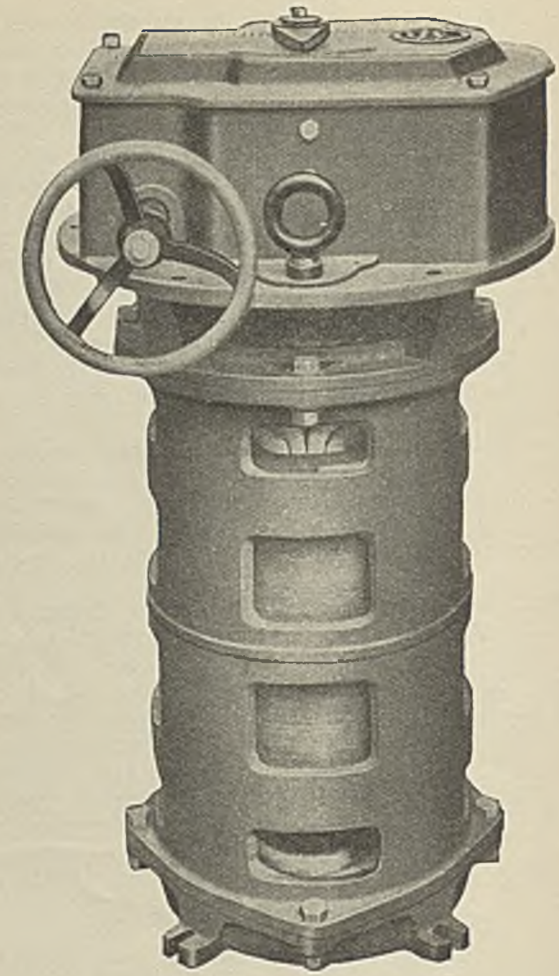


Fig. 6

In the case of pumps, even if there is no necessity to vary the speed of the pump over an appreciable range it is often of great importance to have the speed exactly right as if the pump is running a little fast it may be seriously overloaded whilst if it is running slightly under speed it may be doing much less than its correct duty. In the case of a d.c. motor driving a pump it is common to provide a small amount of shunt regulation in the control gear so that the speed may be set exactly but with an a.c. machine it has been generally accepted that this facility could not be obtained.

A somewhat similar state of affairs exists in the case of fans, and in the case of a main colliery fan it is also often necessary to provide means for running at a reduced speed at the week-end. For this purpose very often two motors are installed to drive the same fan.

Turning to haulages again we have a demand for speed control. In the main this speed control is obtained by the use of a slipring machine with resistances in the rotor circuit. These resistances whether of the liquid or rheostatic type are generally regarded as a nuisance, particularly when the situation is such that a flame-proof enclosure is required: an alternative sometimes resorted to is the use of a squirrel cage motor with a clutch on the haulage and when reduced speeds required they are obtained by slipping the clutch. This, however, is far from being satisfactory as it rapidly leads to mechanical troubles with the clutch. In fact, in many instances the operator, realising that his clutch will not stand up to such treatment, resorts to inching the motor round by means of his controller. Controllers can be built to withstand such treatment but more often than not unsuitable gear is installed and the electrician finds he is continually being called in to attend to the contacts. In any case inching will not give a steady speed but will cause the tubs to progress in a series of jerks.

As a result of many years' experience in the manufacture of mining electrical control gear it was realised that the position was unsatisfactory and an examination of the situation together with consideration of the types of squirrel cage motors which have become available in recent years showed that it was possible to apply a squirrel cage motor with voltage control to these various drives.

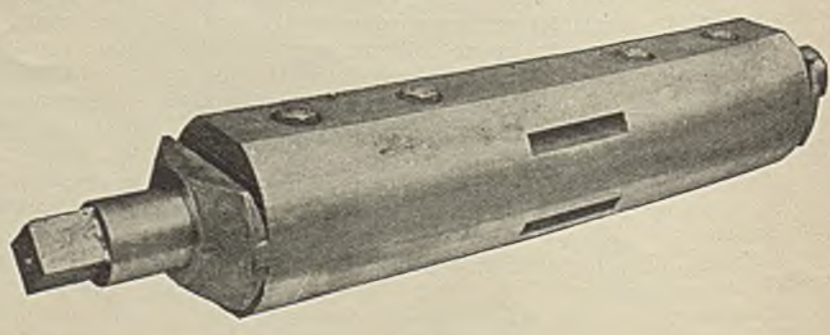


Fig. 7.

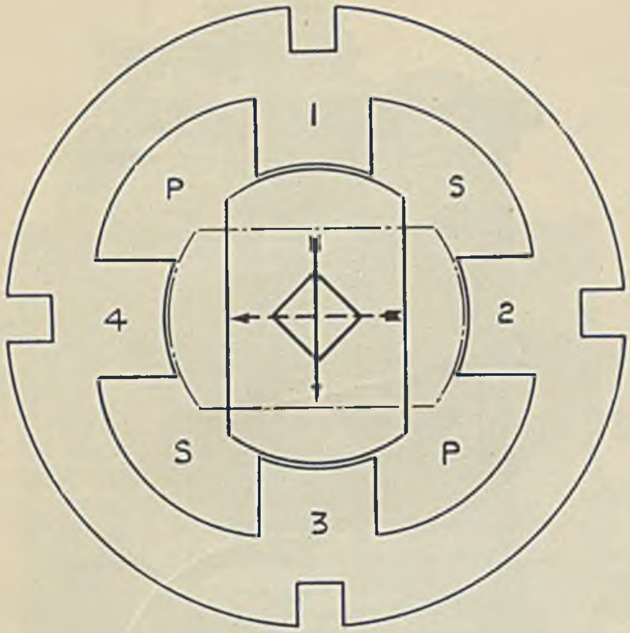


Fig. 8.

The apparatus used to control these squirrel cage motors is the Barbour Inductor (Figs. 5 and 6). This in itself constitutes an infinitely variable auto transformer in which the simple act of turning the handle raises the voltage in a smooth stepless manner from a predetermined minimum up to line voltage or above, if necessary. This inductor is a simple piece of apparatus and has no sliprings, brush gear or flexible connections. It consists essentially of a fixed stator and a movable rotor. The latter has no windings on it but is an assembly of interleaved steel laminations and copper plates as shewn in Fig. 7. The stator carries two windings —primary and secondary, each situated in a pair of slots, the two pairs being at right angles to one another. The rotor is mounted within the stator in such a way that by turning the rotor through an angle of 90 deg. the voltage induced in the secondary winding is changed from a maximum in one direction to a maximum in the other direction.

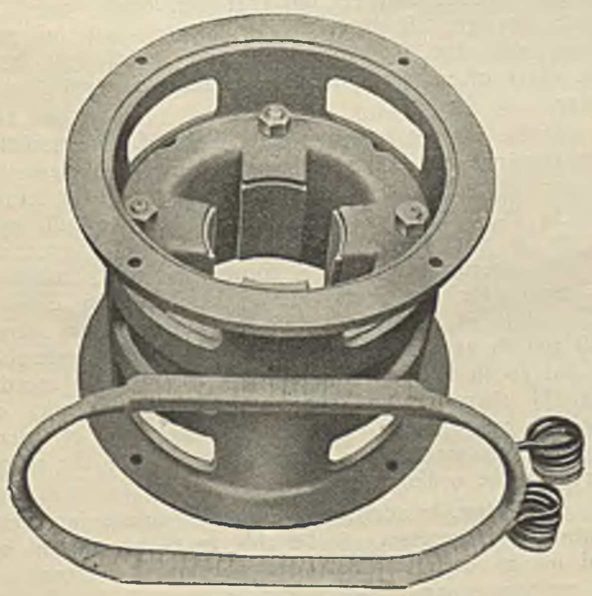


Fig. 9.

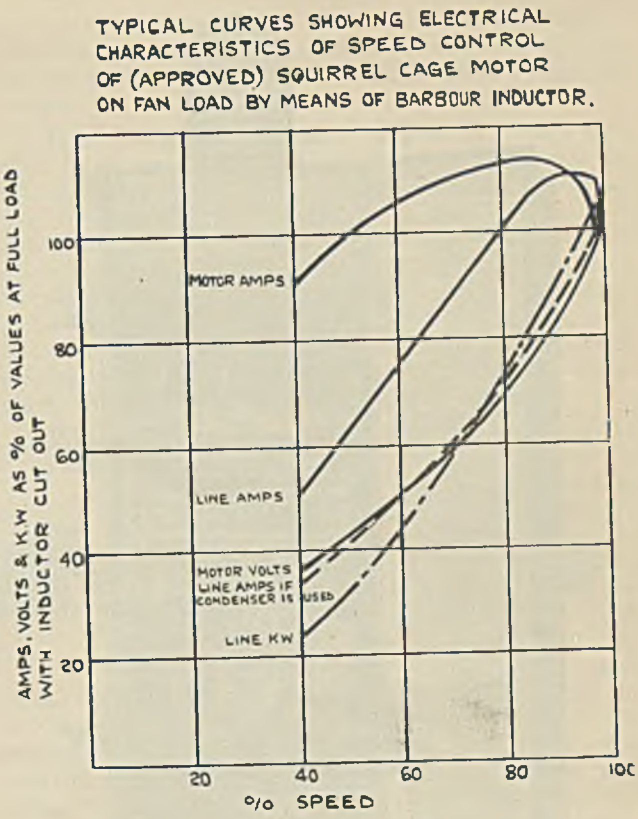


Fig. 10.

Thus, by means of this inductor it is possible to start and stop a squirrel cage motor without any switching whatever and this method is an excellent one to adopt for any really severe duty, where the expense is justified. As, however, the cost of the Inductor is naturally proportional to the amount of voltage variation provided, and a variation of 30% below full volts,

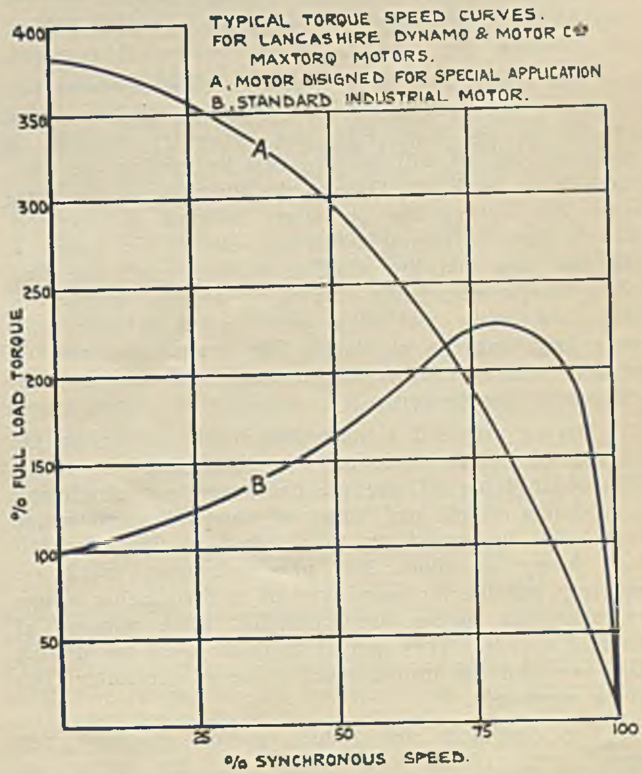


Fig. 11.

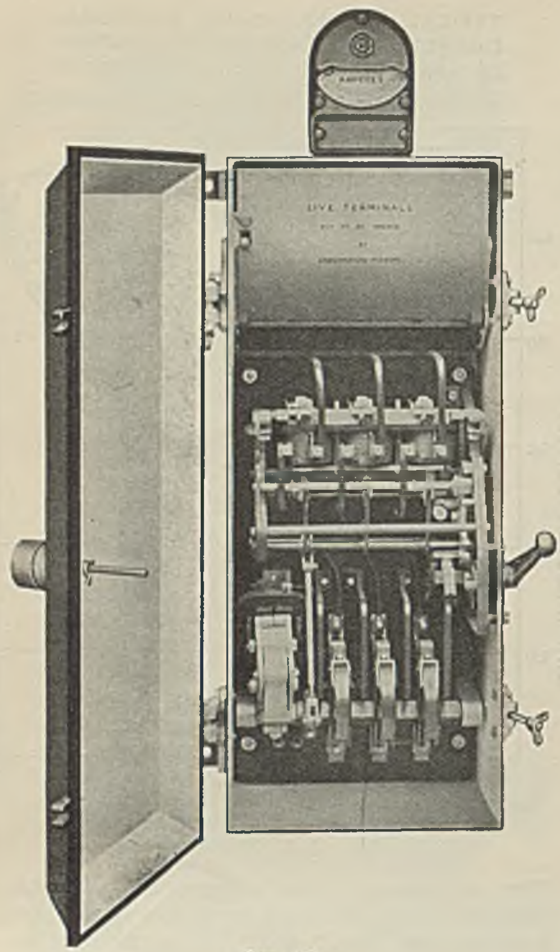


Fig. 12.

i.e. down to 70% of full volts is sufficient to reduce the starting torque to half that of which the motor is capable, it is more usual for economic reasons to provide suitable switchgear for switching on and off and for effecting the reversal of the motor, if required.

The sketch, Fig. 8, is a diagrammatic representation of the stator and rotor, the primary winding being situated in the slots P.P., the secondary winding in the slots S.S. It will be seen that by turning the rotor through an angle of 90 degs. the direction of the magnetic flux cutting the secondary winding is reversed. Fig. 9 shews a typical stator and one of the coils. It will be seen that the winding is very much like that of a transformer, being located in a small number of slots and unlike that of a motor which is distributed in a large number of slots. The construction adopted renders it easy to secure adequate insulation and mechanical support for the coils.

Having provided a convenient means of varying the stator voltage the question of suitable motors arises. The older types of squirrel cage machines developing a maximum of full load torque at standstill which torque rises with the speed up to about 2 to 2½ times full load torque at about 80% of synchronous speed are not very suitable for speed control as their rising torque characteristics makes them unstable when running at reduced speeds. They can at times be used for driving fans provided the torque speed curve of the latter rises at the same rate.

The conditions for stable running at any given speed are: (i) the volts applied to the motor are such that at that speed the torque given by the motor is

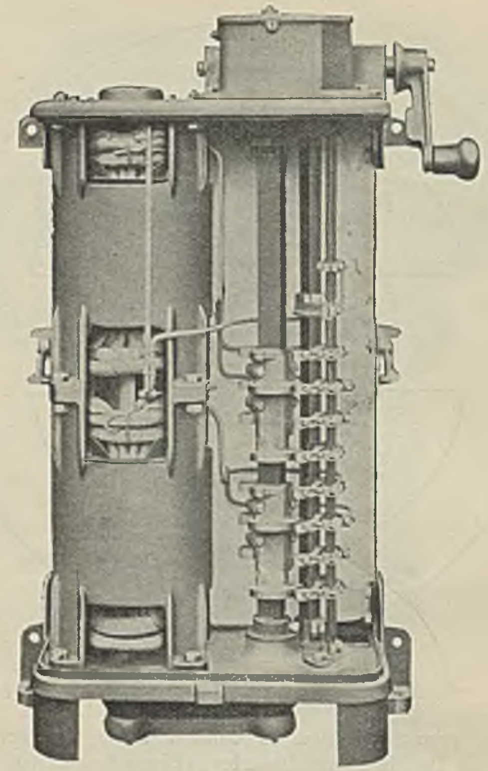


Fig. 13.

equal to the resistance of the load: (ii) with the volts kept constant a slight increase of speed will cause the resistance of the load to become greater than the torque given by the motor, and *vice versa.*

It is possible to procure motors with a somewhat modified rising speed torque characteristic which are quite suitable for fan and pump duty.

Fig. 10 shews the electrical characteristics of speed control of a squirrel cage motor on fan load by means of Barbour Inductor. It will be seen that the line k.w. and amps. after a slight initial rise, fall rapidly as the speed is reduced. A comparison between the curves of motor and line amperes shews the transformer effect obtained by the use of the Inductor: with stator resistance control the motor ampere curve will also be that of line amperes, so that the losses would be much heavier. If desired a condenser can be provided with the Inductor equipment, which will have the effect of reducing the line current to a still lower value.

In the case of haulages quite different characteristics are required. A common specification for haulages is to start normally against not more than full load torque but to be capable of starting against twice full load torque in emergency, also to be capable of creeping at 25% speed against 33⅓% torque for thirty minutes. A motor for this duty must, therefore, be capable of exerting at least twice full load torque from standstill and its speed torque characteristic should preferably be flat so that it will run steadily at the slow speeds. Fig. 11 shews typical speed torque characteristics of squirrel cage motors giving: (A) the type of curve which is necessary for a haulage motor; (B) the rising curve on the ordinary machine.

In practice, in addition to providing means for speed control, it is necessary to be able to switch current on and off as desired. This can be done by means of an entirely separate switch but in general this is not very convenient as it is much better for the operator

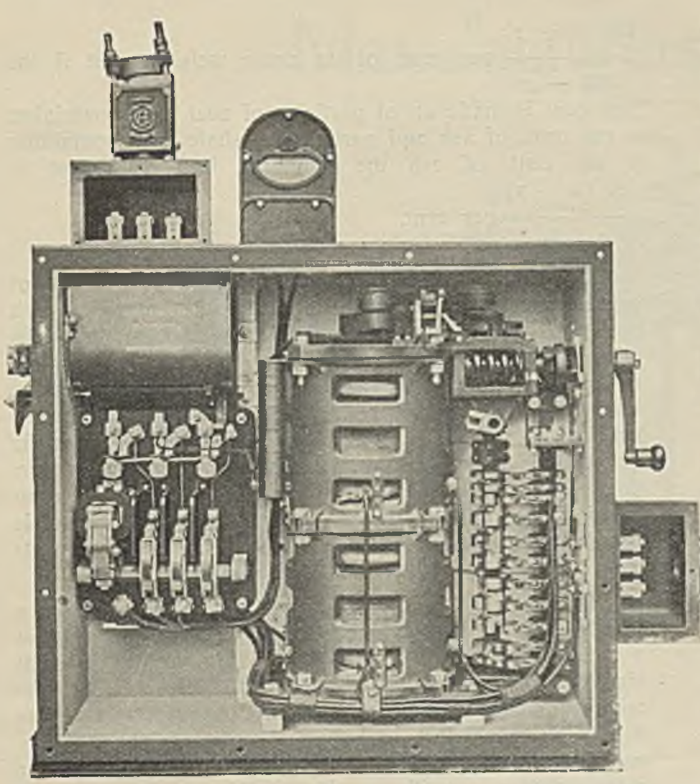


Fig. 14.

to have only one handle to deal with. A suitable form of main switch is illustrated in Fig. 12. This is a panel which contains an isolating switch, three no-current and overload releases and an electro-magnetically operated contactor. This panel is inter-connected with the Inductor and the arrangement is such that the first movement of the handwheel from the off position completes the circuit of the contactor coil so that the latter closes and causes the motor to start and run at its slowest speed. Acceleration is, of course, obtained in the usual way by turning the handwheel until the desired running speed is obtained. Should the voltage fail, or an overload occur, or should one of the supply leads be interrupted the contactor will fall out thus disconnecting the motor. In order to restart there is a little hand resetting interlock on the panel which must be operated and the controller must be returned to the off position. In the ordinary course of operation the operator will not need to touch this panel but can start and stop as he wishes by turning the controller handwheel. A Barbour Inductor suitable for use with such a panel is shewn in the next illustration, Fig. 13.

A still better arrangement is to incorporate the isolating switch and protective features in the same enclosure as the induction controller. In this case the cost of installation is reduced to a minimum as all that has to be done is to connect up the supply cable to the incoming terminals and connect the motor to the outgoing terminals. You then have one compact piece of apparatus complete with isolating switch and all the current carrying parts are safely enclosed and cannot be got at without first opening the isolating switch rendering them all dead and safe to handle. The illustration, Figure 14, shews a panel arranged in this way. This is a reversing equipment and it will be seen that there is a drum shaft which according to the direction in which it moves causes the motor to run in one direction or the other, this drum shaft being interlocked with the contactor so that circuit is always made or broken on the latter. The whole arrangement is controlled by one handle, which is turned clockwise for one direction of rotation and counter-clockwise for reversing.

This arrangement is typical of what is usually supplied for haulage work and can be arranged for use on voltages up to 3300. The apparatus is of the air-break type thus eliminating any risk of oil gas explosion. It also considerably facilitates maintenance as, once the main cover has been opened, all the working parts are very accessible. As has already been stated all current making and breaking is done by the magnetically operated contactor. This is a very great advantage when apparatus is frequently operated as the degree of contact is something which is beyond the operator's control.

With gear in which the main circuit is made directly by hand operated contacts a good deal of trouble is experienced due to the operator making indefinite contact, particularly when inching; instead of moving the controller full on to the first notch he very often just pushes it up to the point where he sees the machine move and then he immediately switches off. The result is very rapid burning of contacts and continual replacement thereof. When a contactor is used all the operator can do is to produce somewhat similar conditions on the contacts which complete the contactor coil circuit. The current flowing here is very small and the contacts will withstand a good deal of such usage, whilst on the main contactor itself there is no possibility of indefinite contact—the switch is either fully in or it is open and consequently very little burning takes place.

Acknowledgments are due to Mr. R. H. Barbour for assistance given in preparing this paper, and to the Lancashire Dynamo & Motor Co. Ltd., for the curves used in Figure 11.

WEST OF SCOTLAND BRANCH.

Joint Meeting of Scottish Branches.

At a joint meeting of the Scottish Branches of the Association held in Shotts Public Hall, Shotts, on Saturday, 21st November last, there were present more than eighty members and their friends.

Mr. Arthur Dixon, President of the West of Scotland presided, and he was accompanied on the platform by Mr. F. Beckett, Vice-President of the Association, and Mr. Webster of the Lothians Branch.

After Mr. Dixon had stated the object of this particular meeting, Mr. James Walker of the Lothians Branch gave a lecture on "Electrical Breakdowns and Repairs" illustrated by lantern slides.

At the conclusion of the lecture tea was kindly provided by Mr. Matthew Brown and Mr. A. S. Murdoch of the Shotts Iron Co. Ltd.

Mr. Beckett then addressed the meeting.

Mr. Beckett said he had been a member of the Association for about twenty-two years. Previous to the formation of the Association of Mining Electrical Engineers, a number of men felt that the Institutions of Engineers and Mining Engineers did not cater sufficiently for the needs of those who were engaged in the electrical side of the mining industry, and they thought it would be a good thing to form a separate Association, so that these people who were engaged in the mining industry, whether business or maintenance men, could meet together to discuss and give their own experiences.

Mr. Beckett said that the objects of the Association were, to foster the application of electricity to the industry of mining, thus tending to increase safety; also for the general advancement of the members of the Association, by the exchange of opinions between them, resulting in increased efficiency.

Mr. Beckett said the industry had come through some very trying times during the last fifteen or twenty years. Despite that, however, the Association had flourished. The membership was taken from all grades: there were Mr. Horsley, the Chief Electrical Inspector of Mines, and his Chief Assistant; there were manufacturers, maintenance men, etc. who all met together, all of whom endeavoured to give the others the benefit of their experiences. Branches had been formed all over the country; there were now ten branches and seven sub-branches, where numerous papers were read and discussed. There were also various active Committees engaged regularly in special work for the Association, such as, for example, the Prizes Committee, the duty of which was to judge the papers which had been read at the various Branches and recommend the prizes awards for the best papers given during the year.

Mr. Beckett said he thought that all young electricians would be well advised to study for, and secure, the Association Certificates of Competence.

Mr. Arthur Dixon proposed a vote of thanks to Mr. Matthew Brown and Mr. A. S. Murdoch for their hospitality, and to Mr. W. McCallum for making the necessary arrangements for the meeting. Mr. Walker was also thanked for his practical and interesting lecture.

ECONOMICS OF COAL CLEANING.

R. D. ROGERSON.

(*Continued from page* 154).

The cost to the colliery company of cleaning coal to a certain ash content is the sum of a number of contributory expenses and losses. The cost of passing the unwashed coal through the washery or cleaning process and the cost of maintaining the plant in running order must be met. To this must be added the interest on capital, depreciation, rates and insurance, and the cost of supervision. Another important consideration is the possibility of troubles in the washery which may lead to irregular working, and especially to periodical stoppages of the colliery itself. By far the most serious cost, however, is the loss of a large portion of the pit output in the form of refuse, and the loss of combustible matter in the refuse. The refuse from the most efficient washery does not contain 100 per cent. of ash. The shale associated with the coal seldom contains more than about 80 per cent. of ash with a further 10 per cent. of combined water. Even in the most modern process of coal cleaning it is impossible to prevent the passage of a certain quantity of useful coal into the refuse. The purest coal that can be prepared always contains "fixed" ash by reason of the mineral matter more or less intimately mingled with the coal substance.

If the raw coal consisted of particles, some yielding no ash on incineration and others yielding 100 per cent. of ash, by the most efficient methods of cleaning, the ash content of the raw coal *x* per cent., could be reduced *y* per cent. in the washed coal by removing

$$\frac{100\ (x - y)}{100 - y}$$

per cent. of its gross weight. But if the raw coal is made up of particles of coal each containing *a* per cent. of ash and particles of shale each containing b per cent. of ash the minimum loss of output is

$$\frac{100\ (x - y)}{b - y}$$

per cent.

It is well known of course, that pit coal does not consist simply of a number of individual particles with one given ash content and a number of other particles with another given ash content, but that it contains particles of more or less pure coal of specific gravity less than 1.35 and more or less pure dirt of specific gravity greater than 1.6. Between these two specific gravities is a proportion of middlings. This, however, does not invalidate the calculation, because in commercial coal cleaning, the control of the process is based (and the efficiency of operation is often calculated) upon the results of float-and-sink analyses.

The operator knows that, if all the particles below a specific gravity pass into the clean coal, he will obtain a satisfactory product, and that if all the particles of higher specific gravities pass into the refuse he is sustaining no loss of saleable or useful output. Just as it may be satisfactory to base the control of the washery on the results of float-and-sink tests at some one or more arbitrary specific gravity, so too, for the purpose of our calculation it is permissible to regard the clean coal as a mass of particles (the floats) with a certain mean ash content. The refuse may be regarded as another mass of different particles (the sinks) also with a mean ash content. In industrial practice, it is never possible to effect a sharp and complete separation between the particles comprising the floats and those comprising the sinks, and it is usual to consider that the washing is performed with a satisfactory overall efficiency if the clean coal contains not more than 2 per cent. of sinks and the refuse contains not more than 2 per cent of floats.

A better way of expressing the efficiency of washing is by the ash contents of the washed coal and the refuse. Thus, if a float-and-sink test indicates that the coal can be divided into two fractions, one including A particles with a mean ash content of *a* per cent., and the other B particles with a mean ash content of *b* per cent., it may be decided so to wash the coal that, as far as possible, the A particles with *a* per cent. of ash are collected as clean coal, and the remaining B particles are rejected. The limitations imposed by inaccuracies operation on the commercial scale, however, prevent the maximum efficiency from being obtained, and, under average conditions, the washing is as nearly perfect as circumstances permit if the fractions obtained by washing contain : clean coal, $a + 0.5$ per cent of ash ; and refuse, $b - 3$ per cent. of ash. Thus the clean coal may be expected to contain 0.5 per cent. of ash more than the theoretical minimum, and the refuse 3 per cent. of ash less than the theoretical maximum.

The loss of output sustained is then :

$$\frac{100\ (x - y - 0.5)}{b - y - 3.5}$$

or, in the case cited, where y = a, the minimum practicable loss is :

$$\frac{100\ (x - a - 0.5)}{b - a - 3.5}$$

x being, as before, the ash content of the raw coal.

Manufacturers' Specialities.

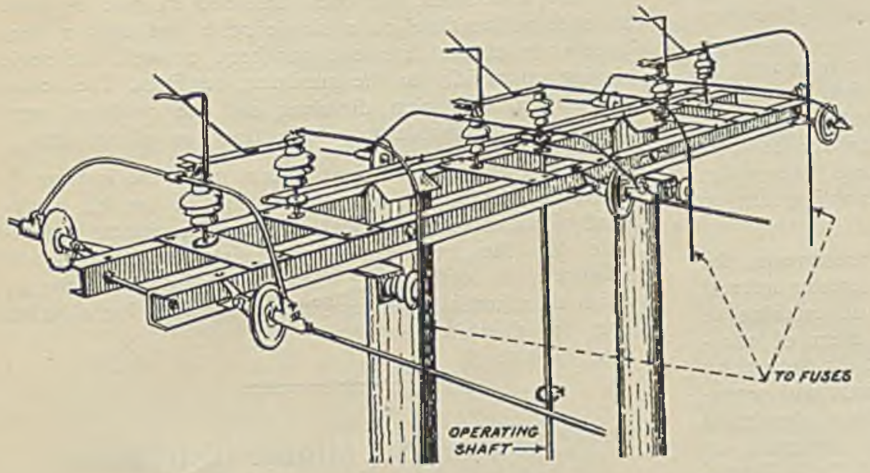


Fig. 1.—An M.V. triple-pole Air-Break Switch as fitted to a standard H-pole.

Air Break Switch for 11,000 volt Overhead Lines.

The Metropolitan-Vickers Electrical Co. have recently introduced a triple-pole air-break switch of unusual design for current breaking duty and possessing important characteristics. Designed for rural distribution and for top-of-pole mounting, this M.V. equipment may be used as a section switch, for teeing off, or as a terminal switch. The normal rating of the standard switch is 100 amperes at 11,000 volts. The general construction and arrangement of the standard units are shewn in the illustrations herewith. The framework is designed for line pulls up to 3000 lbs. per phase, and no additional external supporting irons are necessary. All the ironwork is heavily galvanised by hot dip process.

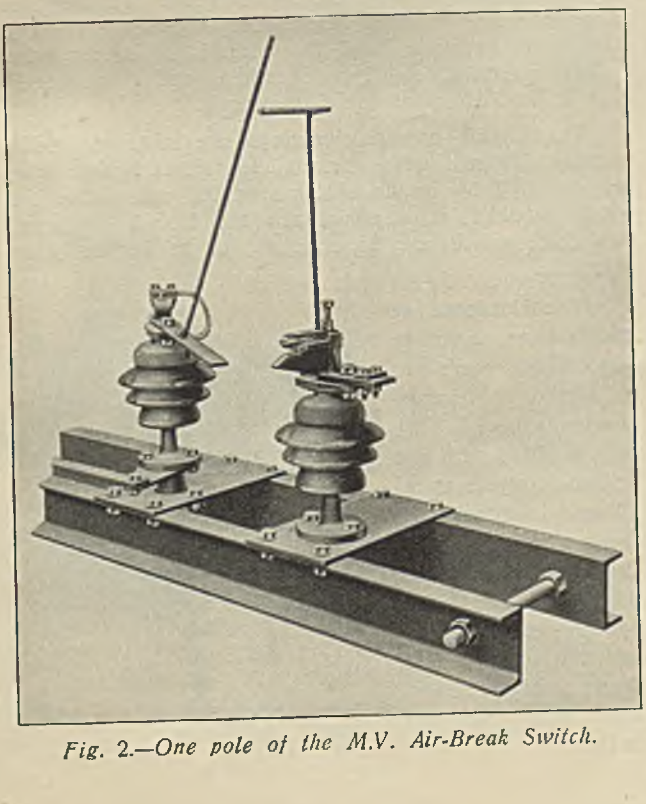


Fig. 2.—One pole of the M.V. Air-Break Switch.

The switch contacts are of the high pressure type, the break being taken up on arcing horns which are so designed that the arc is started at the highest point above any earthed metal. The insulators are of the pin type of superior quality having high flashover values: all insulator cementing undergoes a steam curing process.

The diagram, Fig. 1, shews the adaptability of the gear for erection on the top of an ordinary "H" pole; the standard pattern being suitable for twin poles of any centres between 3 ft. 6 ins. and 5 ft.

The same diagram illustrates the operating movements which are made by means of a vertical torsion shaft from ground level.

The general layout of the gear is designed so that through-line connections and teeing-off can be carried out in a most simple manner.

The Metropolitan-Vickers Company have also produced an air-break switching equipment of similar general design but suitable for double line sectioning and a tee-off : in this case the equipment is for mounting on a four-member pole.

B.T.H. Rotary Converters.

The British Thomson-Houston Co., Ltd., have recently received an important order from the London, Midland and Scottish Railway Co., for six 1500 k.w. rotary converters, with starting panels and transformers. These machines, which will augment a large number of B.T.H. rotary converters already in service on the L.M.S. system, are required in connection with the increased traffic on the Euston to Watford line, and will be installed in existing substations where B.T.H. rotary converters are already operating. Each of the new machines will be rated at 1500 k.w., 630 volts, 25 cycles, 500 r.p.m., and one unit will be installed in each of the substations at Camden, Bushey, Stonebridge Park, Dalston, Willesden and West End Lane.

Further progress in the changeover at Birmingham from 25 to 50 cycles has necessitated alteration to the electrical equipment of the rotary converter substations at Court Road and Cheapside. The contract for this work also has just been awarded to the British Thomson-Houston Company. It covers the reconstruction of three rotary converters at Cheapside substation with alterations to the existing EHT switchgear and automatic control gear, and the modification of three rotary converters and transformers at Court Road substation. The rotary converters are rated as follows ; three at 1000 k.w., 750 r.p.m., 470 volts, for lighting and industrial power service, one at 500 k.w., 1000 r.p.m., 550 volts, for traction and lighting service, and two at 500 k.w., 1000 r.p.m., 550 volts, for traction service.

"Meg" Earth Tester.

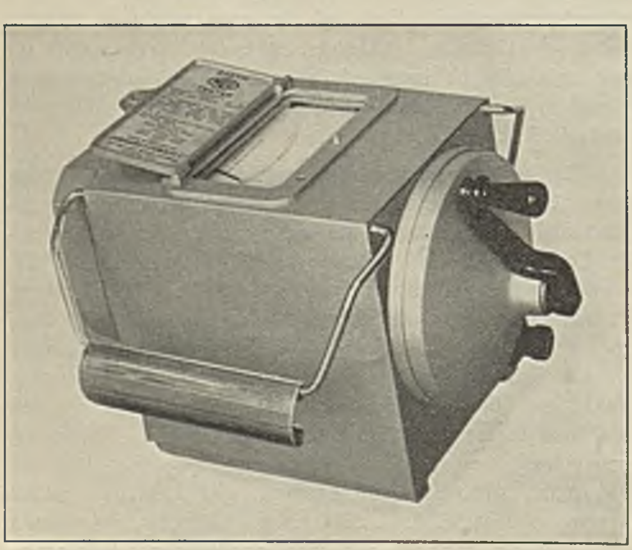
For the recent annual joint exhibition organised by the Physical and Optical Societies, Evershed and Vignoles Ltd. this year adopted a new and satisfactory method of exhibiting their various products. This included a series of very simple diagrams prepared to shew clearly the basic principles upon which each Evershed instrument is designed. The advantages of this method for an exhibition of this character are obvious, the general appearance of the instruments themselves is secondary to the study of diagrams enabling one to understand their principles and designs.

Of the many well-known Evershed instruments, the latest addition to the "Meg" family is of greater interest to mining electrical men: the question of earthing in connection with electrical systems is to them of paramount importance. The importance of actually measuring the value of "earth" on a system is obvious and recognising this, Evershed & Vignoles Ltd. have developed the "Meg" Earth Tester, an instrument designed on exactly the same principle as the "Megger" Earth Tester, and which gives direct readings in ohms of the resistance to earth without calculation or adjustment; the reading being unaffected by soil electrolysis or vagabond currents.

The "Meg" Earth Tester is a handy portable instrument of light weight, similar in appearance to the "Meg" Insulation Tester, the ohmmeter and generator being contained in a cast aluminium case. The external dimensions are 5½ ins. by 9¼ ins. by 6¾ ins. and the instrument weighs less than 8 lbs.

The case is fitted with three terminals, one at the generator handle end marked "Earth", and two others at the ohmmeter end of the case marked "P" and "C" respectively.

The use of the instrument is extremely simple. The "Earth" terminal is connected to the earth plate or metal structure the resistance of which is to be measured, and two spikes one being connected to the "P" and the other to the "C" are terminal driven into the ground, each about 50 feet from the earth plate and from each other. The instrument is so designed that the resistance which the temporary testing spikes make with the earth does not materially affect the accuracy of the reading. A water main can be used instead of the spikes in the ground, the "Earth" terminal being connected as previously described and the other terminals joined together by a wire which should then be connected to the water main.



The "Meg" Earth Tester.

The instrument has been designed to give as wide a range as possible on a single scale and thus a very open scale at the zero end has been evolved, the scale closing up rapidly to the maximum readings. The scales are divided into ohm divisions and the readings, zero to 30, are obtainable to within fractions of an ohm.

The low price and light weight make the instrument especially suitable as a standard unit in the kit equipment of all mining electrical and other engineers responsible for the maintenance of mains and distribution networks. A leather case can be supplied, the strap of which is adjustable for carrying by hand or for slinging from the shoulder.

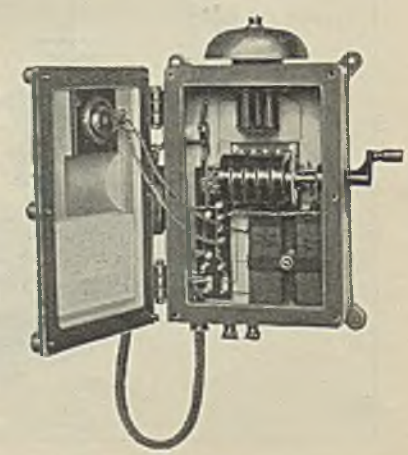
New Ironclad Mining Telephone.

A new type of magneto mining telephone has been developed by Heyes & Co. Ltd. This latest "Wigan" speciality embodies improvements ensuring that the speaking and ringing are of the highest order. Eight of these instruments on one circuit can be operated quite satisfactorily. A general idea of the form of the instrument will be gathered from the illustration. It consists essentially of a simple robust ironclad case with flanged machine faced flame-proof joints into which the various components are assembled. It is fitted with hinged lid thereby facilitating inspection, and the easy replacement of batteries. Shrouded screws are incorporated as an effective means of preventing interference by unauthorised persons.

The magneto is of the heavy bridging five-magnet type. The ringer is bi-polar and polarised, and fitted with a best quality bell metal gong 5½ ins. diameter. The transmitter is of the capsule shot type, and the receiver is bi-polar mounted in a special case with fibre cap and suspended from the switch hook. The receiver cable consists of two cores each consisting of two strands of steel wire and five strands of copper wire, rubber insulated, cab tyre sheathed, and "armoured" with a dry whipcord braiding overall.

The circuit operating springs are of best quality phosphor bronze with special alloy contact tips: they are operated by means of an insulated cam. The batteries supplied as standard are the No. 1 "Wigan" dry cells, which are so arranged as to be easily replaceable.

The telephones are supplied as complete instruments ready to be placed in commission immediately. They may be fitted with one or two receivers as required: in either case the general design is the same: the overall dimensions are 20 ins. by 13½ ins. by 6¼ ins. and the weight, with single receiver, 53 lbs., with two receivers, 58 lbs.



The "Wigan" Mining Telephone.