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The Value of the Convention.

Writing as on the eve of the A.M.E.E. Convention—for the Cardiff Festival will have come and gone ere the postman handles our June issue—we would offer certain ideas and opinions which may help to influence to a favourable decision those who are still hesitating whether to attend. The programme, as set out in full on page vi., shews how well the men of the organisation committee have been able to gauge the requirements. The South Wales Branch has always been one of the most virile and enthusiastic in Association affairs ; hard work, perseverance and honest convictions are commonly recognised as infectious qualities. Though we will not make so bold as to say, either, that the A.M.E.E. deserves well of the mining and engineering community at large, or that the influential public recognition accorded to its annual convention is but its proper due, we can in all sincerity acknowledge the favours received. It is good to have and enjoy the generosity of those highly-placed people and bodies who so freely give of their best to enhance the prestige of the Association and to fill the cup of hospitality for the delectation of members and friends. Such services demand the honourable response.

There is no need to elaborate, item by item, upon the programme in detail—it is an admirable blend of business and pleasure—but there are some features of this event which are often overlooked. The annual meetings of the Association provide the only regular opportunities for all members to meet on common ground ; to learn of recent progress and of future aims ; to criticise and to mould the policy. Personal contact with representative members from all parts of the country is only possible on these occasions—and there is very much of national importance afoot now-a-days which mining electrical men could with profit discuss informally amongst themselves. Uppermost, for example, are the many complex problems arising from the vastly grown intervention of the Government which, for good or ill, has permeated irresistibly through the industrial to the commercial and now even to the technical practices and principles of the greater national industries, particularly those of electricity and coal. The mines electrical inspectorate has been at one step increased many fold ; certification, examinations, and compulsory measures with contingent liabilities are in the near-distance view of mining electrical men ; even in regard to technical detail, such as mines' lighting and the engineering equipment generally, the engineer is, to all intents and purposes, seemingly to be commanded by the State. Verily, these are strange times, and they are fast-running. Members of the Association of Mining Electrical Engineers, through their close-linked mining and electrical interests, are in the main stream of this spate of political pressure. They have much to discuss amongst themselves, when they foregather from all parts of the kingdom in the free aand easy circumstances of a holiday convention. The Association has played a great part in aiding the progress of national endeavour ; it will be called upon for still weightier action and influence in the early future years.

The catholicity of the membership of the Association, because it covers the whole gamut of status ranging from junior electrician to college professor, exercises to the greatest advantage when all meet in person. The novice and the expert fraternise with those of ripe years and experience. In effect, all stand to gain by the tempering influences which prevail and the outcome is that true appreciation of values which begets sound judgment. So will the Association as a body be the better equipped with a policy forceful and right, enabling it to present a four-square front in the field when these reformative proposals come to assume definite shape and the issue is the consolidition of the well-intentioned though vague, ideas and notions of the "mother" of parliaments.

Then again, there are quite a number of junior members who have missed the point that to take part in the annual convention of their Association is one of the most comfortable methods by which they can grow accustomed to the ways of the world. It usually means a trying, and with certain temperaments a distressful series of experiences for the ambitious youth when he steps out from his narrow parochial circle to join in the thronged field of great business affairs. Mainly for lack of opportunity or facilities the acquiring of the personal confidence and self-reliance of a broad outlook is one of the most difficult parts of a complete education. The annual convention "knocks the corners off" smoothly and very efficiently ; it brings introductions to many useful people ; it provides a place wherein the young man can "find himself" and so it helps him forward in his career as no other method can ever do, and no other method can be so pleasant and simple in its operation.

Exhibition of Coal Face Machinery.

An exhibition of considerable importance is to be held in the Edmund Road Drill Hall, Sheffield, from 2nd to 10th October next. The hall is well suited for an exhibition of this character, and the fact that some of the stands measure 44 ft. by 33 ft. indicates that an extensive range of coal face machinery will be on view. All the available space has been taken up, and it will be seen from the following list of exhibitors that a thoroughly representative display is assured :—

Anderson Boyes & Co., Ltd., British Jeffrey-Diamond, Ltd., Climax Rock Drill & Engineering Works, Ltd., Cowlishaw, Walker & Co., Ltd., Gullick, Ltd., Hardypick, Ltd., Mavor & Coulson, Ltd., Mining Engineering Co., Ltd., Sullivan Machinery Co., Richard Sutcliffe, Uskside Engineering Co., Ltd., Hugh Wood & Co., Ltd.

The exhibition will not be open to the general public, but admission will be only by invitations to be issued by the organisers : The Coal Face Machinery Exhibitors' Association. It is certain to be of more than ordinary interest to all those closely interested in the coal mining industry—including colliery owners, managers, engineers, and machine men—all of whom will wish to take this opportunity of familiarising themselves with the important developments in all types of coal face machinery and plant in recent times.

Arrangements have been made with the Railway Companies to issue cheap tickets to those attending the exhibition or conferences connected therewith.

Mines Department's New Official Testing Station.

The Secretary for Mines announces that he has decided to institute official safety tests for electrical apparatus intended for use in mines where, although the normal conditions are considered sufficiently safe to permit the use of electricity, it is, nevertheless, necessary to take precautions against an explosion of firedamp.

The object of these tests is, briefly, to determine by actual explosion experiments whether the electrical apparatus under test is "flame-proof"—that is to say, whether the design and construction are such as will securely prevent the ignition of a small quantity of firedamp inside the apparatus from giving rise to an explosion of firedamp outside it.

By arrangement with the Safety in Mines Research Board, and with the help of their staff, a new Testing Station for this work has been erected and equipped by the Mines Department at Harpur Hill, Buxton, adjoining the Board's Research Station there ; and the new Station will be ready for work by the middle of April.

All enquiries and all applications for tests which (so far as possible) will be dealt with in the order in which they are received, should be addressed to the Under Secretary for Mines, Mines Department, Dean Stanley Street, Westminster, S.W. 1.

It is understood that in view of the institution of these official tests, the University of Sheffield has decided to discontinue the unofficial tests of the same character in the carrying out of which for some years past it has rendered valuable services to the safe development of the use of electricity in the mines of this country.

Safety in Mines.

A large number of colliery owners and workers attended the special session of the National Safety Congress at Leeds on May 12th.

Mr. W. Hargreaves, LL.D., J.P. (Chairman of the West Yorkshire Coal Owners' Association and of the Henry Briggs, Son and Company Ltd.) inaugurated the meeting and in his opening speech dealt with local rescue and safety work. He made it quite clear that whilst the ambulance men were always on the spot they would prefer to prevent rather than cure ; they were accepted with the fullest confidence by all ; the Safety First movement was however, sometimes criticised as inculcating cowardice.

Mr. C. G. Ingall (Industrial Safety Engineer N.S.F.A.) in the course of his speech explained the term "safety first". He stated that it originated on the railways, where the cardinal rule was "that the *Safety* of the Public must be the First Consideration". Mr. Ingall was convinced that 90 per cent. of the accidents were due to the failure of the human element. Safety in Mines was dependent on the study of accident causes, and very little could be done until the influence of the human factor was recognised by the State and also by the owners. Miners must be educated to the safety of themselves and of others. The effect of educating the miner against running thoughtlessly into danger had been all to the good.

Close observance of the Regulations under the Mining Act would certainly considerably reduce the number of accidents, which were often the result of ignorance of those regulations or, in some cases, wilful disregard of them. Because a man was a miner, it did not mean that he should be expected to be thoroughly conversant with the regulations. Indeed, there were very few, if any, at the present meeting who would care to pass an examination on those regulations. The address by Mr. Ingall concluded with a brief summary of the work and objects of the National Safety First Association.

Subsequent speakers at the meeting were Mr. J. C. Micheson (Morris & Shaw Ltd., Birch Coppice Colliery, near Tamworth), Mr. N. Baster (Colliery Manager, The South Kirkby Collieries) and Mr. George Cook, H.M. Inspector of Mines. All of these speakers felt that they could only repeat what Mr. Ingall had already said. Mr. Micheson said that he thought the miners were especially in need of a Safety First Campaign. It was necessary to educate the men in preference to compelling them to observe the letter of the regulations. Production would not suffer, as a safe workman would be confident and would apply all his energies to his job. He explained at some considerable length the Safety work that was being carried out at his Company.

2400 Volt, Earth-Sheathed, Aerial Cable.

In residential districts with overhead systems of supply, trees often constitute a problem for the distribution engineer. Drastic trimming and mutilation, often seem to be unavoidable, and where local amenities have to be preserved some other means is sorely needed. The conditions required a form of self-supporting cable, combining all the conveniences of the uninsulated weatherproof wire such as its capability of being strung up in convenient spans, with the useful properties of an underground cable i.e., high insulation and earth sheath.

Henley's have recently supplied to the Toronto Hydro-Electric System (Canada) a length of 0.0225 sq. in. single core 2,400 volt cable for self-supporting suspension on concrete poles, to meet these requirements. The conductor is of high conductivity copper, varnished cambric insulated, jute braided, armoured with a single layer of 23/0.072 in. special aluminium alloy wires, jute braided and compounded overall.

This design provides an insulated cable suitable for overhead use and light enough to allow of the use of concrete poles which cannot be used to take the dead-end strain of the usual messenger construction, i.e., lead covered cables suspended from a catenary or messenger wire.

The aluminium alloy armouring gives the desired longitudinal strength and at the same time gives a metallic protection which, unlike steel, results in no hysteresis loss when used in connexion with a single phase a.c. supply. This special form of armouring is covered by patents.

Fundamental Principles Applicable to Mine Lighting.

R. D. ROGERSON, M.E., A.M.I.E.E., M.Inst.M.E.

THE general question of improved lighting in and about mines is being careful consideration by the Mines Department at the present time. The writer proposes to consider some of the fundamental principles as applied to lighting generally and also the safe use of high frequency current for bulk lighting at the coal face.

THE SAFE USE OF HIGH-FREQUENCY CURRENT IN BULK LIGHTING.

Professor Thornton, in the course of research work, found that at a frequency of 150 periods the least current that could cause ignition from a lighting circuit was 23.5 amperes at 200 volts. The least direct current at the same voltage was found to be 0.4 ampere. The ratio for safety in favour of alternating current is, therefore, not less than 60 to 1, a strong argument in its favour for safe lighting at the coal face. At 25 volts, at least 140 amperes at 150 periods is required to flash the most explosive mixture.

The reason why ignition by electric sparks or hot wires is always critical, i.e., occurs sharply at or above a certain level and not below it, is that ignition is a form of chemical and physical combination that is not dependent on heat received or temperature-rise, except perhaps in certain very few cases, but on electrolytic action ; this must reach a definite value before anything happens, just as a relay or circuit breaker must have a definite current passing before it operates.

The reason why the alternating current risk changes with frequency is as follows :—

When the frequency is low (the arc in opening lasts never more than a quarter-period) the time of heating of the poles is longer, and so is the duration of the arc in contact with the gas. A small current then causes ignition either by contact between the flame of the arc and the gas or between the gas and the pole after the arc is extinguished, as red hot poles have a great facility in igniting gas, and the reducer lasts longer than the arc itself. As the frequency is raised, the duration of the arc is less and more current is necessary to get ignition while it lasts or by contact with the hot pole after it has gone out. This goes on until the current is so large that the poles are made white hot in 1/500th part of a second and remain very hot for 1/50th part of a second or so, and is sufficient to make ignition easy when the gas comes in contact with the crater on the hot pole at the moment the arc is opened. Ignition may occur by contact with the arc or the pole crater. If with the arc, it would require more current as the frequency is raised, because it lasts so much shorter time. If with the pole, the quicker the arc gets out of the way the easier hot-spot ignition occurs. Thus, after a certain point, ignition becomes easier as the frequency is raised. Eventually the current falls to a value so low that the poles refuse to be heated to ignition temperature while the arc lasts. To get this result we must work with non-inductive circuits.

THE NATURE OF LIGHT.

Light may be defined as a sense impression formed by the eye. Thus while we are unable to discern the actual path travelled by light, we know that when it strikes an object the object is illuminated and the eye is consequently aware of the fact. The progress of light through the ether at the rate of 186,000 miles per second is by means of waves and the distance between the crests of such is known as the "wave-length." Nature's primary light source is the sun which, on a cloudless day, illuminates the surrounding objects to such a high degree that the light reflected from them is often harmful. Sunlight is compounded of the seven colours : Red, Orange, Yellow, Green, Blue, Indigo, Violet. If these colours were painted in proper proportions on a wheel, and in their proper sequence, only a white colour would be perceived when the wheel was turned on a pivot through its centre. If one colour be omitted, one colour would be seen—a tinted colour the result of the union of the remaining six.

THE DIFFERENCE BETWEEN LIGHT AND ILLUMINATION.

Light and Illumination are widely different terms in the sense that light may be described as the "Cause" and illumination as the "Effect." Since the light which is really effective for the purpose of vision is that which enters the eye from the object viewed, it is necessary to make a lamp supply *enough* light to the *object*, so that the amount of light reflected from the object to the eye will be sufficient for clear and comfortable vision. In other words, the "luminosity" of the object is an important factor, and this depends not only on the light received, but upon the reflecting power of illuminated object. Materials vary widely in reflecting power. White surfaces reflect as high as 80 per cent. of the incident light, while black objects reflect only a fraction of 1 per cent. This factor, in the opinion of the writer, is one of the chief causes of miners' nystagmus.

The reflecting efficiency of the walls of the travelling roads and working places in mines is extremely low and the greater proportion of the light which strikes them is absorbed or is not reflected—it is lost. Many experiments have been carried out with coloured glass in electric safety lamps to minimise this loss, but with little success. From the foregoing, it will be obvious that it is the reflecting surfaces upon which the light rays fall that would require to be treated before reflective efficiency can be increased The ingenious idea of whitewashing the roofs and sides of haulage roads, which was due to an enterprising official some years ago, would, if applicable and practicable in all parts of the mine, go far towards the elimination of the eye diseases which we are now, unfortunately, so frequently confronted with. Unfortunately, the cost of the universal application of this preventive method, apart from the humane point of view, would be far in excess of the costs imposed on the industry by the disease.

It is very gratifying indeed to observe that the Mines Department in their Supplementary Proposals contemplate introducing compulsory measures both in regard to white-washing certain parts of the workings and to the treatment of roadways by incombustible dust, which must be *white*. The proposals are as follows :

Indirect Lighting.

(1) "For the purpose of improving the lighting of roadways by means of reflected light, the incombustible dust with which they are treated in pursuance of Part 1 of the General Regulations dated 30th July, 1920, shall (except for slight discolouration caused by impurities) be *white*."

(2) (a) "So far as practicable, the roof and sides of all haulage roads at places where persons are regularly at work shall be kept effectively whitewashed ; and this shall be done in particular at all sidings, landings, passbyes, haulage junctions (offtakes) and the tops and bottoms of all permanent self acting inclines."

(b) "All pit bottoms and mid landings or insets which are in use for the descent and ascent of workmen shall be effectively whitewashed."

(c) "The tops and sides of engine rooms, motor rooms and rooms containing transformers or switchgear shall be kept effectively whitewashed."

Should these proposals become statute, the benefits would be considerable. It is a matter of regret, however, that owing to the fact that over 80 per cent. of the workmen who develop eye trouble are employed at the coal face these proposals will be of very little benefit to them.

GLARE.

Glare has been described as light out of place. It may be "direct" or "reflected", i.e., direct from the light source to the eye (as caused in mines by bare lamps in the line of vision) or reflected from a highly polished object. Both forms are capable of causing discomfort and a consequent loss of efficiency in work.

The size of the pupil regulates the amount of light which enters the eye. Light shining from a brilliant source, however small, directly into the eye tends to contract the iris, or reduce the pupil, thus making general vision more difficult. Under ordinary lighting conditions where only reflected light enters the eye, the iris is expanded, and this produces greater visibility and less eye strain. The former condition is commonly known as glare, which causes eye strain, and the resultant headaches and indisposition to work, etc.

The use of portable hand lamps in mines is one of the contributory causes towards the ill effects of glare. This type of lamp is also responsible for excessive strain due to defective reflection, and in consequence insufficient illumination, in relation to the relative positions of the eye and the lamp. Notwithstanding the universally accepted benefit of the portable cap lamp as compared with the hand lamp, over 80 per cent. of the lamps installed in mines last year were hand lamps. The cap lamps are in some districts condemned for face workers, owing to the inconvenience and weight of the battery slung on the back of the wearer. This inconvenience could perhaps be overcome by the manufacturers supplying the cable leads between the battery and lamp in such lengths that the battery could be placed conveniently near the workman without it requiring to be slung on his back.

LIGHT CONTROL.

It should be remembered that an object is visible solely through the agency of the light reflected to the eye, not as a result of the amount of light emitted from the lamp to the eye. When light falls on an object, it may be returned by Reflection or taken up by Absorption.

Absorption of Light.

An object which is dark or nearly black will absorb the majority of the light rays striking it, even though the light source itself is extremely brilliant. In underground lighting, due to the black nature of the surroundings, the greater proportion of light rays emitted by a lamp are absorbed and not reflected to the eye. Without some means of improving light reflection, illumination can therefore only be improved by raising the candle powers of the light-giving units.

Reflection.

A light coloured object will reflect a large proportion of the light rays and be thereby readily visible. When light rays fall upon a coloured object, all the rays with the exception of those of the same colour as the object itself are absorbed, while the rays corresponding in colour to the object are reflected to the eye, thus providing the sensation of colour and transmitting to our brain the composition of the particular colour.

Contrast.

It will be appreciated that visibility depends largely on contrast, such as that produced by shadows or difference in colouring. If the object is dark, such contrasts are reduced to a minimum, and therefore powerful illumination is necessary to accentuate the shadows. If the objects are light coloured, the shadows are more easily distinguished and the illumination can therefore be reduced.

Light Transmission.

The transmission of light may be affected by materials which are either transparent or translucent. A transparent substance will allow light rays to pass through it in a definite direction, but the effect of a translucent object will be to break up the incident light rays and re-radiate them in many directions, i.e., diffusion.

Diffused Reflection.

A matt surface, such as a white ceiling, will reflect incident light rays in all directions, i.e., scatter the light instead of returning it as a direct reflected beam. A combination of two surfaces, such as a mirror and a matt has the effect of partially reflecting and partially diffusing or scattering the light, and forms an ideal surface for practical purposes. A vitreous enamelled steel reflector *of properly designed contour* is the finest example of this scientific and practical combination.

Total Reflection.

A beam of light shining on glass is partially reflected and at certain angles is reflected to such an extent that it may be considered as acting as a mirror, directing the light into definite directions (Fig. 3 I : R_1 R_2). This principle has been employed in various glass reflectors, by making the surface of the glass into a series of prisms, which act as reflectors to the incident light.

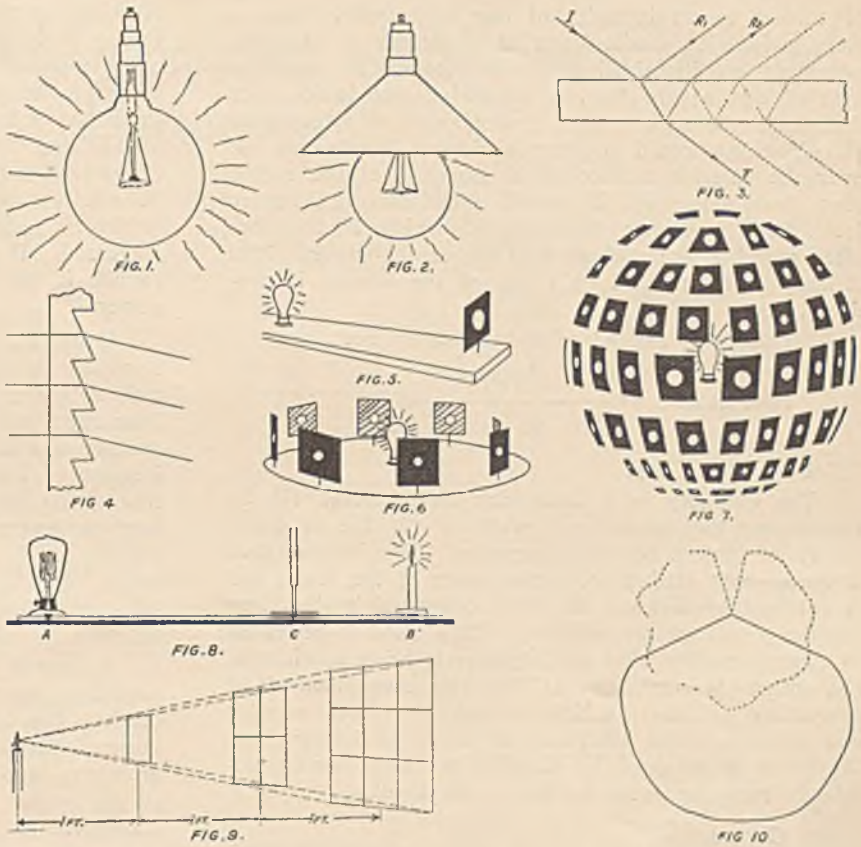
Refraction.

When light passes at an angle through a piece of plate glass of uniform thickness, it emerges at the same angle as shewn in Fig. 3, I : T. If the glass is thicker in one part than in another, the light ray will be bent towards the thick part, or refracted (Fig. 4). Good examples of the practical application of this principle of light control are

the complicated and highly efficient series of lenses used in lighthouse projectors and in certain forms of street lighting refractors.

MEASUREMENT OF LIGHT.

It has been said that every science passes through two stages: first, the process of discovering the laws by which it is governed: second, the period when such laws can be verified by actual measurement. This applies particularly to the science and art of Illumination. In the outline of proposals by the Mines Department regarding the contemplated new Lighting Regulations, the candle-power of lamps in use will require to be ascertained periodically. The process of finding the candle-power of lamps is given below.



Candle-Power.

During the progress in the development of illuminants, it has been found practical to measure their intensity in terms of a standard size and type of candle. The term candle-power is used to designate the strength of the light emitted by any given source in a definite direction, and is the unit of measurement now used by international agreement.

Horizontal Candle-Power.

Horizontal Candle-Power (H.C.P.) is the candle-power of a lamp in the horizontal position (Fig. 5).

Mean Horizontal Candle-Power.

Mean Horizontal Candle-Power (M.H.C.P.) is the average of the candle-powers of the lamp as distributed over a horizontal plane (Fig. 6).

Mean Spherical Candle-Power.

Mean Spherical Candle-Power (M.S.C.P.) is the average of the candle-power from the lamp in all directions (Fig. 7). A measure of the candle-power in any direction does not give any indication of the total amount of light emitted by a source. For instance, the beam from a lighthouse may develop 2,000,000 candle-power in one direction, whereas the mean spherical candle-power of the light source may only be in the neighbourhood of 500 M.S.C.P. By permitting the light from the lamp under test (A) and the light from the testing standard (B) to illuminate a screen (C) fixed between them and to so vary the distance between the lamps and the screen until the illumination falling thereon is equal to the eye, a definite reading is obtained (Fig. 8).

It therefore follows that

if D_1 = Distance of lamp under test from screen
and D_2 = Distance of standard from screen

$$\therefore \text{C.P. of Lamp} = \text{C.P. of Standard} \times \frac{D_1^2}{D_2^2}$$

As previously mentioned, however, it is necessary to distinguish with care the difference between the intensity of *light* emitted by a given source and the intensity of *resulting illumination* at the place where the work is done. Thus, while the light emitted by a source is measured in candle-power, the intensity of illumination received at the work is measured in Foot-Candles.

The Foot-Candle.

The Foot-Candle is the intensity of illumination at a place one foot distant from a light source of one candle-power. The greater the distance from the source of light the less is the illumination received per unit surface. This value can be computed by the law of inverse squares, which is as follows—

$$\text{Illumination in Foot-Candles} = \frac{\text{C.P. (Candle-Power)}}{\text{Distance from light source squared}}$$

For instance, at one foot distant from a light source of 16 C.P. 16 foot-candles will be obtained, while at two feet away, 4 foot-candles will be the result (Fig. 9). The above formula is true when the light rays strike the plane of illumination at right angles. Should they strike at some other angle, then the formula is changed to

$$\text{Intensity} = \frac{\text{Candle-Power} \times \cos^3\theta}{(\text{Height above work})^2}$$

θ = Angle between light ray and a perpendicular dropped from the lamp.

The Lumen.

Light being a form of energy, it is important that the unit of energy should not be confused with the unit of intensity (candle-power). The "lumen" or unit of luminous flux may be considered as the unit of energy, in much the same way as the inch is the standard of rainfall over a certain area, as it embodies the area iluminated by a light of definite intensity and the degree to which such area is illuminated, namely, one square foot

of surface to an intensity of one foot-candle. Thus, a lamp giving one candle-power at a distance of one foot, providing an illumination of one foot-candle over an area of one square foot, is producing one lumen over that area. As such a light giving an equal intensity in all directions would produce a similar illumination all over the interior surface of a sphere one foot radius (two feet diameter), it would illuminate 12.57 square feet, thus producing 12.57 lumens, which is therefore often stated as the equivalent of one candle-power. Thus a lamp may be rated in terms of the lumens it produces, e.g.,

$$\text{Lumens} = \text{Foot-Candles} \times \text{Area in Feet, or}$$

$$\text{Foot-Candles} = \frac{\text{Lumens}}{\text{Area in square feet}}$$

Efficiency of a Lamp.

The efficiency of a lamp may be measured (1) by considering the candles per watt, or (2) the luminous output of lumens per watt expended. The first method is really only stating the performance of the lamp, and is obtained by dividing the watts consumed by the lamp by the candle-power emitted. Care should be taken to express exactly what candle-power is being considered, i.e., either M.S.C.P. or H.C.P. The other method of expressing efficiency, which is now the more popular and reliable, gives efficiency in terms of Lumens per Watt. It is obtained by dividing the total lumens obtained from the lamp by the watts input.

Polar Curves.

It is often necessary, in order to predetermine the distribution of light, to know how the candle-power of a lamp source varies in different directions ; and for this purpose, readings of the candle-power of the lamp or fittings are taken in many directions and various angles and the results plotted as a polar-curve on squared paper.

The curve then indicates readily the intensity in a given plane. Fig. 10 shews two distribution or polar-curves, which represent equal light outputs, the upper being from the lamp itself and the lower representing the lamp equipped with a scientifically designed reflector.

EFFECT OF VOLTAGE VARIATION IN LIGHTING CIRCUITS.

It is well known that the voltage underground is sometimes considerably below that of the supply source on the surface and that, moreover, it is also liable to a certain amount of fluctuation ; it is useful, therefore, to know how the candle-power of a lamp varies with the voltage. Let us assume that the normal voltage of the lamp is 100 volts and that the luminous output is 100 lumens ; now if the voltage, due to drop in mains or some other cause, be reduced to 90 volts, the luminous output is reduced to 67 lumens. In other words, a reduction of 10 per cent. in the voltage causes 33 per cent. decrease in the candle-power of the lamp.

The light emitted by a lamp depends upon the temperature of its operation and a change of temperature of the filament of 1 per cent. produces a change of light output of 11 per cent. When, as very often happens, a 110 volt lamp is operated on 100 volts with the idea of extending its life, it is obvious that the filament of the lamp will be working below its normal temperature, and the resultant light output very greatly reduced.

Under-Running of Lamps on a Lighting Circuit.

The practice of using lamps of higher voltage than the supply in order "to make them last longer" is economically unsound. The value of the lamp as a light source is in the effective light which is emitted, and not altogether in the original cost of the lamp itself. It has to be remembered that the cost of current consumed by a lamp is usually more than the initial price of the lamp itself and that the lamp is merely the means of converting current into useful light. Therefore, when its efficiency as a medium is reduced, the illumination (which is paid for in hard cash) is proportionately decreased. If a 110 volt lamp is operated on a 100 volt circuit, it causes a decrease of 33 per cent. in candle power.

When the voltage across a lamp is raised, its consumption in current increases, also the watts on which cost of energy is based. The following table is rather interesting, as it indicates the relationship between the voltage of a lamp and the amount of light obtained. An increase of 1 per cent. on voltage increases the consumption of the lamp by 1.7 per cent., and the output of the luminous energy by the lamp is increased by 4 per cent.

Increase of Voltage.	*Increase of Light.*
1%	4%
10%	40%

It cannot be too strongly emphasised that lamps should be operated at their rated voltage and the more efficient the lamp the more important does this point become. Under-running a lamp does not realise any economy, but has exactly the opposite effect.

Example.

Consider a 100 watt gasfilled lamp. Assume cost of lamp 5s., cost of energy 1d. per unit and average lumens throughout life of 1000 hours = 935 lumens.

Cost of energy for lamp giving 935 lumens for 1000 hours is 8s. 4d.

∴ Total cost of Lamp giving 935 Lumens for 1000 hours is 5s. + 8s. 4d. = 13s.4d.

Now consider that lamp running at 10 per cent. below its rated voltage and that its life is extended thereby to 2000 hours—a generous assumption.

The lamp being operated at 10 per cent. below its correct rated voltage, the light output is reduced 33 per cent.

Lumens output is therefore only 636 lumens.

Ten per cent. under-running of the lamp lowers the watts consumed by 15.5 per cent.

Watt consumption therefore is only 84.5 watts.

Cost of energy for lamp giving 636 lumens for 2000 hours is then 14s. 1d.

Cost of lamp remains at 5s.

Total cost of lamp giving 636 lumens for 2000 hours is then 19s. 1d.

At this rate the total cost of lamp giving 935 lumens for 1000 hours is 15s. 2d.

The cost of the same amount of light under normal voltage conditions was only 13s. 4d.

In other words, the light emitted actually costs 15 per cent, more when a 100 watt lamp is operated on a circuit voltage 10 per cent. below the rated voltage of the lamp. In addition, it should be noted that lamps have a normal useful life and at the end of that period deteriorate rapidly. Old blackened lamps should be replaced with new ones, as it will be found cheaper in the long run, and will provide a more uniform standard of lighting. It is wisely said that to guard the eyes of industry is to guard industry itself.

Proceedings of the Association of Mining Electrical Engineers.

YORKSHIRE BRANCH.

Electric Winders.

A. T. GREIG.

(*Continued from page* 358).

In these remarks up to the present it has been assumed that the power supply has been adequate to cope with the heavy peak load during the acceleration period. In some installations, however, that is not the case and special devices have to be introduced to level out the load on the supply system. These drives usually take the form of a heavy flywheel on the motor generating set, and an arrangement for slowing down the set so as to enable the flywheel to give up some of its energy.

Consider first the application of a flywheel to a Ward Leonard set, which is then known as the equalised Ward Leonard or Ward Leonard Ilgner system. Here, a heavy flywheel of perhaps 30 tons is driven by the converter set, usually through a coupling which can be disconnected if required. This flywheel is sometimes fitted with an eddy-current brake for use in case of emergencies. In series with the generator motor slip-rings is a slip regulator. This consists of a variable resistance controlled by an automatic arrangement. One form of the latter is an induction motor the frame of which is pivoted to enable partial rotation, and which is kept in position by springs. The rotor of this regulator is driven from the motor-generator, usually by a chain, and is connected to the H.T. supply through a transformer. The stator is wound three-phase and connected to the sliprings of the generator driving motor.

Any variation of the speed of the motor generator set naturally causes a variation in speed of the regulator rotor. This speed variation causes the stator to rock on its pivots and contacts are arranged at each end of its limited travel, the closing of which energise the electromagnets of the resistance. The switch consists of a commutator with a vertical spindle, the segments of which are connected to resistances, suitable sparking contacts being arranged to prevent destruction of the brushes. At the foot of the pillar carrying this commutator is a small motor driving a toothed wheel. Over the rim of this wheel a pair of magnets are arranged centrally with pawls attached to their armature. When no current is flowing, i.e., when the speed regulator stator is not making contact, the pawls are disengaged. As soon as contact is made by the floating stator, one or other of the magnets is energised and its pawl makes contact with the wheel and causes the commutator to revolve, thus inserting resistance into the main rotor circuit, until contact is broken and the pawl is released. This apparatus can be adjusted so that the time required to store energy can be varied, thus allowing for rapid or slow winding as the case may be. The diagrams Figs. 4 and 5 shew, respectively, the outlines of a plain Ward-Leonard and equalised Ward-Leonard sets.

A depth indicator is used on these plants, and one arrangement takes the form of a vertical column with two square threaded spindles driven by suitable means

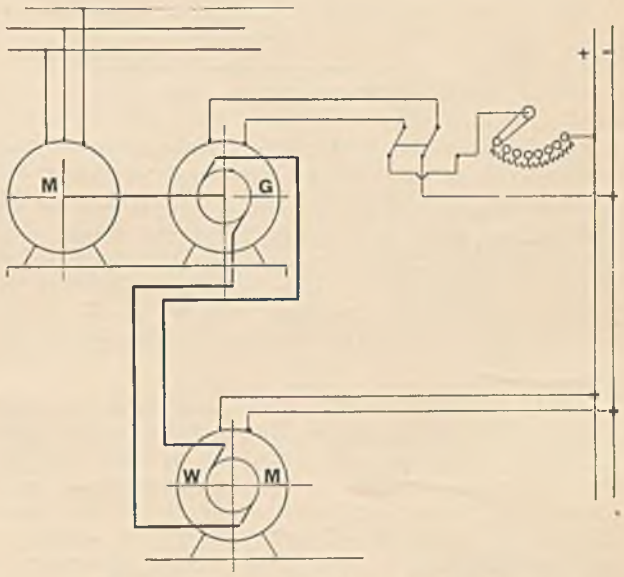


Fig. 4.—Simple Ward-Leonard System.

from the drum shaft. Indicators run on these shafts and shew the positions of the cages. As the cage approaches the end of its travel a gong is automatically sounded, and should the attendant not notice this, a system of levers pushes his controlling lever to zero position. An arrangement is also provided to prevent too rapid acceleration.

In the case of overwind, a catch is released on the depth indicator which being connected by a system of levers to the emergency brake causes this to act and also cuts off the supply to the motors; at the same time it interlocks the controlling lever and prevents this being moved while the brake is on. Arrangements

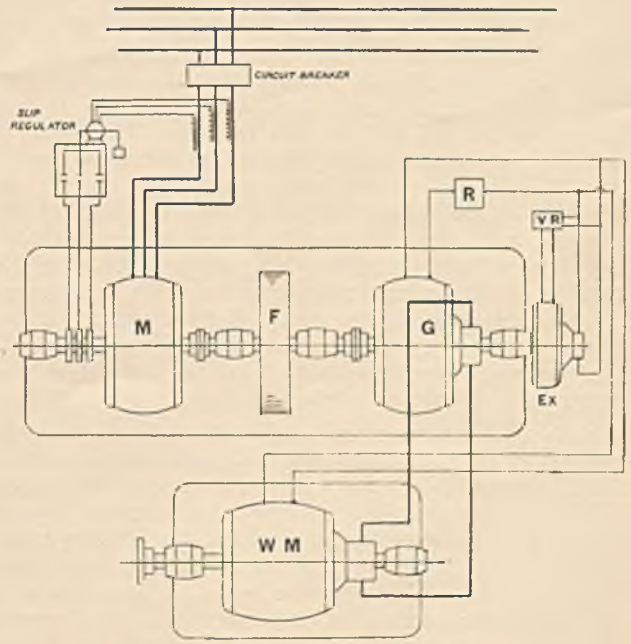


Fig. 5.—Equalised Ward-Leonard System.

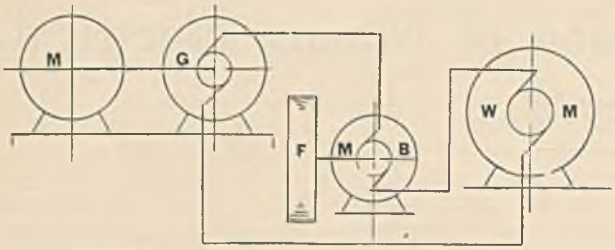


Fig. 6.—The Crepelet System.

however, can be made to raise the cage above bank if necessary without the tripping gear operating.

The equalised Ward-Leonard system is not so efficient as the plain W.L. system; it is, of course more costly and should only be used when the electric supply service is inadequate to cope with the load. It has however, the further advantage that the energy in the flywheel can be used for finishing a wind should the supply fail.

There are other systems which have been used with success. One of these is the Crepelet system, consisting of a flywheel set placed in parallel with the load. The flywheel is driven by a motor or, more correctly, a booster and only supplies the peak load. The principles of the Crepelet system are shewn in the diagram, Fig. 6. MG is the motor generator set and M is the motor driving the flywheel F. This motor is in series with the winder motor WM. M acts as a booster and is wound for the supply voltage, while the winder motor is wound for twice this voltage. When WM is idle its armature is short-circuited and M is across the generator and drives the flywheel at its maximum speed. On starting, the short-circuit is removed, the pressure on M brought to zero gradually and reversed, which causes M to become a generator driven by the flywheel and thus the energy stored in the wheel is given up.

A modification of this system is the converter system. In this arrangement the winder motor is a three-phase slipring machine started in the usual way by a liquid controller. In parallel with the three-phase line is a rotary converter, and the necessary transformer coupled on to a d.c. machine and flywheel. The rotary converter converts a.c. to d.c. and supplies the d.c. machine with energy to drive the flywheel; conversely, when the flywheel is giving out its energy, the d.c. machine feeds the rotary converter with d.c. current, which is converted to a.c. and fed back to the line. The action of the set is as follows, when the load on the winder motor exceeds a predetermined value a regulator on the d.c. machine of the rotary set strengthens the field of this machine and causes it to act as a generator driven by the flywheel, and equalises the peak load by supplying current to the rotary converter, which in turn pumps a.c. current back to the line. When the load is less than the fixed value, the field is weakened, and the d.c. machine runs as a motor, fed by the rotary converter, and speeds up the flywheel.

A continental d.c. system used at Ligny les Aire consists of three machines and one flywheel on a common shaft; the machines being a motor, generator and booster. When the separate winder motor is at rest, the dynamo which is in series with the line and the winder motor, has a voltage equal to but opposite from the line; thus the voltage on the winder motor is zero. On starting the winder motor, the dynamo voltage is decreased by shunt regulation; the voltage across the winder motor thus increases and it speeds up. When the voltage of the dynamo is nil, the winder motor runs at half speed. To increase speed, the dynamo field is reversed and then built up, thus adding its pressure to the supply pressure, the final voltage being twice the supply volts. The motor of the three coupled machines is shunt wound and its armature is in series with the booster on the supply mains. By varying the direction and value of the voltage of this booster, the speed may be regulated, thus enabling the flywheel to give up or store its energy as the case may be. The speed variation is accomplished by means of a regulator in the booster field.

A modification of this is the Lahmeyer Kroemer system. In this case the set is as before, excepting that the generator motor is separately excited. The booster, however, has a series field and a separately excited field which normally cancel each other. It is obvious, that any current change due to fluctuations of the winder motor will disturb this booster field balance, thus giving a positive or negative voltage at the booster terminals, according to which field preponderates. This voltage excites a third field winding shunted across the booster terminals, which field neutralises any effect due to disturbance of the series and separately excited fields and keeps the line current constant.

Lastly, there are two more systems to be considered herein: the turbo-alternator system, and the equalised turbo-alternator system. These are usually used where there is no adequate supply service available or where there is sufficient basis load to justify the purchase of a turbo-alternator. By basis load is meant the load apart from the winder such as haulages, compressor motors, pump motors, lights, etc.

In the turbo-alternator system, a turbine drives an alternator which supplies the basis load. This turbo-alternator drives usually through gearing a Ward-Leonard dynamo, which drives in the usual way the winder motor. The turbine has a very sensitive governor controlled by relays actuated by the current. This governor uncovers extra nozzles in the turbine when peak loads occur, thus throwing these peak loads on to the boilers, which are easily able to stand them. To operate with success, the turbo-alternator should have a fairly high basis load, and should be situated near the winder.

Of the equalised turbo-alternator systems, the best known is the Stubbs Perry. Here, the turbine is geared to a flywheel and drives a variable voltage dynamo, which drives the winder motor. A governor allows the speed to drop about 20% and during winding the peak load is supplied by the flywheel. At light loads and while the cage is stationary the turbo-alternator speeds up the flywheel. A separate high-pressure turbine supplies the basis load. It will be seen that in this system the peak loads are taken by the flywheel and not by the boilers. This system is usually more economical than a steam winder engine with mixed-pressure turbines for the basis load.

Another alternative is to use a back-pressure turbine for the winder and to exhaust this into a mixed-pressure turbine for the basis load. The mixed-pressure turbine can be arranged to be fed from the boilers if the winder is not working. If the mixed-pressure turbine is not working the winder turbine exhausts to the atmosphere.

When braking these turbo-alternator sets two methods can be used, the first is to have an induction motor coupled to the end of the turbo set and exciting with d.c. current as explained before. This motor, if an a.c. supply is available can be used for regenerative braking,

and making occasional winds if suitably rated. In these sets, the turbo-alternator and gearing are arranged with a clutch so that they can be disconnected if required, and the set run on the induction motor. Sometimes, also, the flywheel has a clutch so that the set can be operated without it. The other method of braking is by an eddy current brake.

Mechanical Brakes.

The diagrams in Fig. 7 illustrate the three types of mechanical brakes in general use. These are usually operated by weights acting through levers, and are released by compressed air engines. One type is the post brake, the shoes being pivoted as shewn. The caliper brake is similar in construction, the shoes being pivoted nearer together. The next type is the suspended post brake which consists of shoes mounted on two links pivoted as shewn. In all cases, the weight falls and operates these links thus applying the brake.

The best known types of brake operating gear are the Whitmore and Iversen gears. The diagram, Fig. 7 shews the Whitmore gear applied to a post brake. This consists of a compressed air cylinder A with piston and rod; the end of the rod is attached through a crosshead to the operating weights which apply the brake. Compressed air acting on the underside of the piston releases the brakes. The piston rod passes through a spring box B and has a collar C fixed to it so that the pull of the weights is transmitted from the rod to the collar then through a spring in the spring box to the bottom of this box which bears on the brake lever. Thus, the more the brake operating lever is moved towards the "brake on" position, the greater the fall of the weight and so the greater the compression of the spring giving more pressure on the brake shoes. A ratchet device is incorporated in the operating links to take up wear. The compressed air cylinder is fitted with a dash pot and means are arranged to admit compressed air above the piston and so increase the brake pressure if necessary.

The Iversen gear consists of a piston valve so arranged that a given position of the operating lever corresponds to a given pressure in the brake cylinder, and a corresponding braking effort. Loss of pressure due to leaks, etc., is automatically accounted for by the valve.

Brake weights are usually fitted with dampers, for it is obvious that in the case of hard braking, the falling of the weight and sudden application of the brake will cause a slight stretch in the operating rod, this would set up a recurrent rebound persisting until the whole of the kinetic energy of the weight has been exhausted. The dampers usually consist of springs fitted with oil dash pots fitted between the weights and the rod. The brake shoes are usually lined with wood or some modern friction braking material.

Control Gear.

It is only necessary to consider, say, the single drum Ward Leonard system, as all gears work on a similar principle. The illustration, Fig. 8, shews a diagrammatic sketch of the control gear. The spindle of the depth indicator drives a wheel so arranged by gearing that this wheel makes one revolution per wind.

On this wheel are fixed two cams, one for acceleration and one for retardation. These cams operate on levers which are connected by links to the main operating lever. At the start of the wind the main operating lever is gradually released by the acceleration cam, and at the end of the wind is forced back to zero by the retarding cam. This system was first used by Messrs. Siemens. On the main operating frame are mounted three levers which are interlocked. The main control lever operates the controller and it is in turn, as previously explained, operated on by the levers from the cam gear. The brake lever acts on the brake engine gear and applies or takes off the brake. The third lever is the lever for setting the emergency brake which is called into operation by failure of current, failure of air pressure, overwind, or by hand.

In the case of current failure, the plunger of the brake solenoid falls, raises this rod through this link, rotates the trip shaft and releases the trip as will be seen from the diagram. If the air pressure fails, the brakes will apply themselves, by reason of their construction. It is, however, necessary to open the emergency switch. This is done by the falling of this weight which is normally held up by the air pressure in the small cylinder. Regarding overwinding, when this occurs a lever on the depth indicator is forced over by cams and rotates the trip shaft by means of this rod and lever.

For hand operation, when the operating lever is pulled over to "trip" the rod causes the shaft to rotate, releases the trip and operates the brake. The resetting lever is weighted so that it automatically returns to mid position.

Prevention of Overwinds and Overspeed.

Many protective devices are on the market for the prevention of overwind and overspeed. The principle involved is usually that of a governor which operates the overspeed device and cams to check the retardation. A centrifugal governor is driven through gearing from the drum, as also is the cam wheel as before mentioned. A floating lever follows the movement of the governor sleeve, this lever having a roller at one end. The other end is connected to the trip gear.

During full speed operation, the roller is not in contact with the cam wheel, but as the retardation period begins, the cams on the wheel bear on the roller, and if the speed is not reduced sufficiently, this roller forms a fulcrum about which the governor operates, and thus lifts the trip rod.

A well known device is the Thornewill and Warham "Profile" gear. Here, a cam profiled to the speed curve of the winder lays alongside the screwed shaft of the depth indicator. The governor brings this cam nearer or further from the shaft as the speed increases or decreases. The indicator on the screwed shaft takes the form of a notched wheel. This wheel moves along

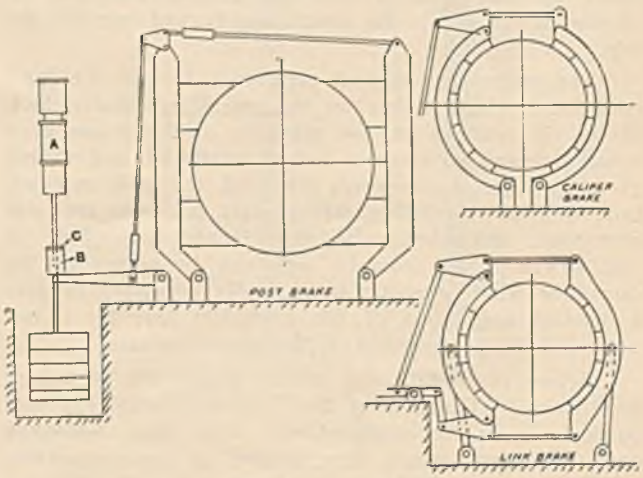


Fig. 7.—Types of Brakes.

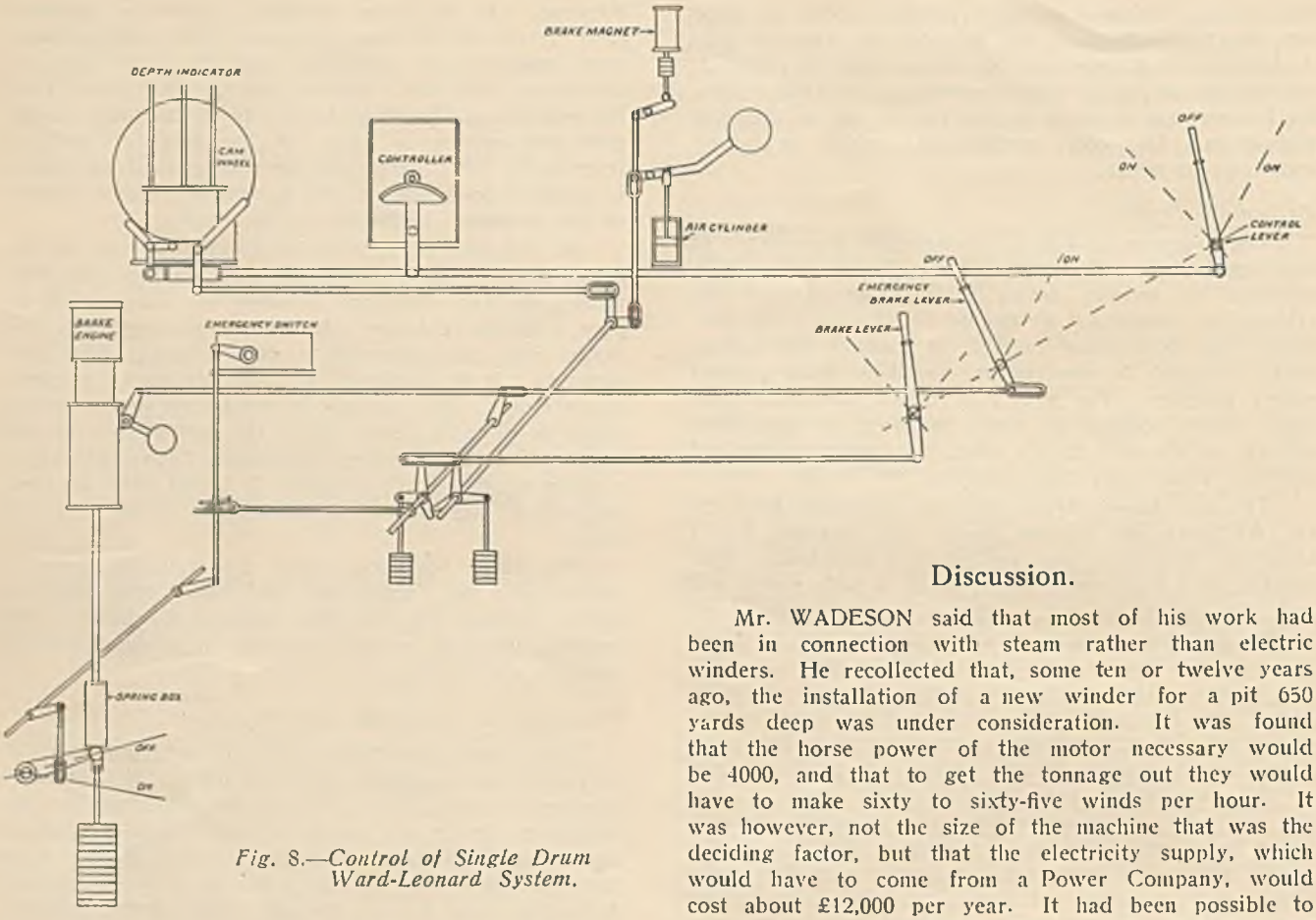


Fig. 8.—Control of Single Drum Ward-Leonard System.

the shaft and also rotates with it. If the speed is too high at any time the cam moves nearer the screwed shaft, and engages with the notches on the wheel, and the wheel carries the cam round and operates the trips.

The "Melling" overwinder is similar excepting that the indicator does not revolve but moves laterally along the screwed shaft and is provided with lugs which engage with notches on the profile cam which in turn is carried on with the indicator and again operates the trips.

Also, the "Whitmore" and "Norton" types are similar, but in these cases a serrated curved arm corresponding to the retardation curve take the place of the cam. The action is similar, the curved arm being lifted by the governor into engagement with the indicator, which carries the arm onwards, and operates the trip.

The author has distinct preference for the "Lilley" controller, which makes an equipment practically foolproof. It operates on the principle of the action of a wheel cam and governor as before mentioned, and affords protection against overspeed, overwind, too rapid acceleration, delayed retardation, wrong start, and also indicates overspeed, and when retardation should commence. It can, moreover, be instantly adjusted, by means of the cams, for winding men. It is hardly necessary to give a detailed description of this controller here for it has been frequently described in technical journals.

Before concluding, the author would like to tender his thanks to the staff of the English Electric Co. and particularly to Mr. Kefford, for their kind assistance and suggestions which were helpful in the preparation of this paper, and also to the lantern operator for his assistance.

Discussion.

Mr. WADESON said that most of his work had been in connection with steam rather than electric winders. He recollected that, some ten or twelve years ago, the installation of a new winder for a pit 650 yards deep was under consideration. It was found that the horse power of the motor necessary would be 4000, and that to get the tonnage out they would have to make sixty to sixty-five winds per hour. It was however, not the size of the machine that was the deciding factor, but that the electricity supply, which would have to come from a Power Company, would cost about £12,000 per year. It had been possible to purchase a steam winder for the amount which it would have cost to run the electric winder for one year.

Mr. Wadeson added that, although he was an electrical engineer, he was inclined to think that electrical winding plant had become too complicated in comparison with a steam winder in which everything was quite simple.

Mr. HOLIDAY, referring to the comment made by Mr. Wadeson, said the diagrams used in the paper looked rather complicated, but thought the diagrams were more intricate than the machines were found to be in actual practice. At the same time, he would be somewhat chary in regard to a decision in favour of an electric plant, quite apart from questions of efficiency and power used. Some time ago, he, Mr. Holiday, had asked a man responsible for the electric winder at a colliery how he liked the electric winder. His reply was, that it was all right so long as the management did not get on to him about the cost but if they raised that subject he would rather have a steam winder.

Mr. STAFFORD said that the subject of the paper was not now so controversial as it was twenty years ago. It was about so long ago that the late Mr. W. C. Mountain gave a paper in Nottingham upon "Electric *v* Steam Winders Commercially," and the conclusion arrived at was that steam winders were superior to electric ones. Mr. Stafford said he did not think that conclusion held to-day. He remarked that with the provision of an outside source of supply then electrical winding came into its own, because an electrical winding machine is more efficient than a steam winder. He said that although the stand-by losses in the former may be considerable, it was more than counterbalanced by the heat losses of steam winders during standing time.

Mr. Stafford stated that with regard to the choice of winders and the question as to whether to use high speeds and light loads or low speeds and heavy loads, he knew several people who used low speed machines and had no cause for regret. He thought that perhaps there was no real reason for this "storm in a tea-cup."

Continuing, Mr. Stafford said it was quite correct to say that electric winders gave much smoother running, but there was no insuperable difficulty in designing steam winders to give very nearly as smooth running.

The great advantage of electric winders was that it could be controlled with reliability and certainty with safety devices. He said that these devices covered every contingency and that was a great point in the favour of electric winders. Mr. Stafford further mentioned that a certain firm had under review at the present moment a type of compressed air braking gear which could be applied at all conditions of acceleration and deceleration.

Mr. J. MANN said that usually when putting in electrical winders there was a great deal of opposition to contend with, but when they had been in use for a time the winding operators said they liked them better than the old steam winding system.

He enquired how, with all the automatic devices, it was possible to arrange for slow running for examining shafts.

Further, he pointed out an instance in Mr. Grieg's paper where two generators were provided and asked what was the reason for the two generators, whether it was a provision for when one was broken down, or was there some other motive.

With regard to the emergency brake, when this had come into operation, due to over-speed or the failure of the supply, what arrangements were provided for getting the weight back to the normal position? Was this done by some reservoir containing compressed air, or by means of hydraulic gear operated by hand? Mr. Mann said he had found it took considerable time to get the weight back by hand.

Mr. GRIEG, replying to the questions raised, said he would deal with the last point mentioned by Mr. Mann first. The emergency brake, as Mr. Mann had suggested, was usually got back to the normal position by means of compressed air.

With reference to the other points raised during the discussion, he could say that under almost all conditions electric winders shewed a saving as compared with steam winders. He agreed, however, that this was dependent upon the cost of the electricity supply, and said that there were some cases where steam winders were better in this respect. The so-called complications looked more formidable in the diagrams than they really were.

In reply to Mr. Mann's other questions, Mr. Grieg said that to arrange for slow running for examination of shafts, a special switch was provided.

The two generators to which Mr. Mann had referred were simply a matter of design. It was cheaper to transport two small generators than one large one, but there was no reason why a greater winder should not be brought in as it was only a matter of convenience.

Mr. MANN said he had experienced considerable trouble due to the use of the air type of dash-pot. He had found that what happened was that, when the graphite pistons had worn very slightly, during the week-end periods the transformer cooled down and contracted and drew up the piston a very small amount. Then, when winding restarted, it rose but did not fall back, but brought the circuit breaker out. Mr. Mann stated that upon changing the dash-pots he got over the trouble.

THE CHAIRMAN (Mr. Higgens) remarked at this stage that with electric winding most of the complications were due to the damping out of peaks.

Mr. GRIEG stated that with regard to peak loads where three-phase winders were used the power stations could usually deal with the peak loads.

He would emphasise that the plain Ward Leonard control type of winder was the most efficient of all, and said that it should be adopted wherever possible.

SOUTH WALES BRANCH.

(P) Earthing of Electrical Apparatus.

J. VAUGHAN HARRIES.

(*Continued from page* 362.)

TESTING.

To meet the requirements of the Mining Regulations all apparatus must be subject to periodical tests to prove its ability to safe working. The principal tests which can be made of earthing apparatus are three in number.

Firstly there is the test of the leakage indicator: this test can be applied continuously to the installation and measures the actual leakage current itself. On circuits not subject to automatic leakage protection, where faults are not severe enough to operate the overload coils of the governing switchgear, a leakage indicator will assist in the localisation of such faults. By this means faults can be found and attended to when in their embryo stage, and thus also helping in the spirit of the law, that all faulty circuits shall be isolated to prevent danger.

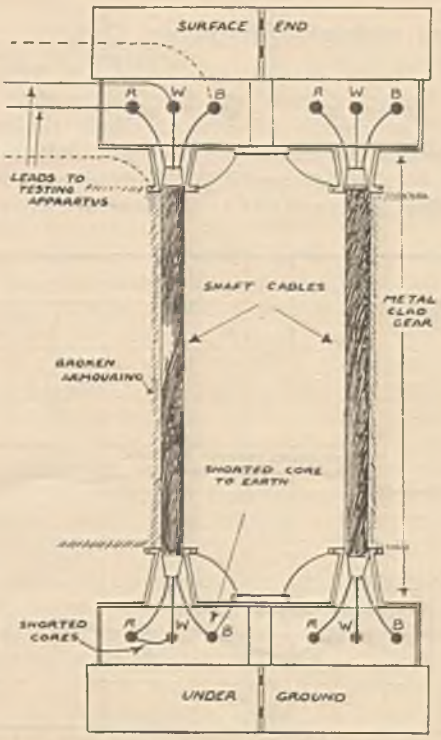


Fig. 4.—Outline of Cable Test.

Secondly, there is the insulation test. It is impossible to separate the subjects of insulation and leakage. Every insulating material is subject to deterioration and it is in this inherent inability to retain dielectric strength that there is always the possibility of leakage to earth. To prove the effectiveness of insulation it is desirable to subject it to a charge of double the working pressure; this is not always an easy matter. Before putting the apparatus into subsequent service, it is usual to apply the double pressure test by means of a testing transformer, this can be done either at the works or on site after erection. In the case of large capacity units, and as an assurance against damage during transit, the latter arrangement is best. Where there are groups of collieries working under a general management, a portable testing transformer is a useful test accessory: it can be used for many purposes at the various collieries, and for none more important than that of localising high resistance faults and, if possible and expedient, breaking them down. The Megger is a useful instrument for ascertaining the state of the insulation: it can be used on all low pressure installations, satisfying the requirements of the Regulations.

Thirdly, there are the earth continuity tests of all bonds, metallic casings and armourings, assuring a definite easy path for the discharge of leakage currents. The method of testing for continuity the armouring of cables is well known. It is represented in Fig. 4 and may be briefly explained as follows: The cable is discharged to earth—a most important first step in the procedure. Phases R and W are short circuited at the far end of the cable a test is made which gives as a result the joint resistance of two cores. Assuming the remaining phase B to be of indentical character to R and W this is joined up to the armour and, testing as before, between the end of core B and the end of the armour at the surface, the joint resistance of one core and armour is ascertained. Thus:—

$$\frac{\text{First reading}}{2} = \text{Res. of one Core.}$$

Second reading — Res. of one Core = Resistance of Armouring.

The foregoing tests can only be usefully applied to single line feeders or in cases where current is led into apparatus by means of tails, and only then when it is possible to dismantle all earthing bonds. It is when testing for continuity the armour of cables attached to metalclad gear that we come up against a trouble due to progress. When duplicate cables and feeders of lead cover and armour specification are bonded by metalclad gear, tests of the individual cable armouring cannot be obtained. Parallel circuits are formed and tests shew a higher conductivity than expected, when compared with the cable makers' actual cable test. Referring to Fig. 4 it can be seen that the armour is eaten away and yet the test would shew continuity. Other paths which tend to affect the tests and offer assistance to the conductivity of the armour are compressed air pipes water mains and rail guides all are normally interconnected to the earthing system. Under such circumstances results of tests can only be accepted in the sense of comparative readings. It is well that the electrician in charge should have a standard test, by which comparisons can be made. If continuity tests were made in the early stage of construction, when the cable is new, it would then be possible to refer to what may be termed a standard armour resistance.

In the testing of the armouring of shaft and feeder cables, it is not good policy to rely on one method. The author prefers the principle of applying one method which needs calculation, and one in which the calculation is ready made. An average figure can then be made and accepted as being correct. Bonds across joint boxes, trifurcating boxes and other apparatus, should have a conductivity at least equal to an equal length of armouring. They should be tested not merely for continuity, but for actual resistance, this will have a far reaching effect upon the overall resistance of the cable system.

Where cables are subject to severe conditions such as for coalcutter and conveyor work or immersion in water, a special earth core forming an integral part of the cable is advisable. Special connectors should constitute part of the control gear, thus securing a substantial connection between surface earth plates and point of usage. Thorough examination for bad connection, corrosion due to water and electrolytic action, breakage of jute serving, will help a great deal in preserving a good earthing system.

RECORDS.

Records of electrical and plant tests and examinations are very important. Always of historical interest, they are invaluable as an indicator of the depreciation or maintenance of condition of the items of equipment. Fig. 5 illustrates the insulation tests of a motor, the variations in the graph are a result of tests taken when the motor varied in temperature. Insulation tests of all apparatus should be taken when the windings are warm the insulation is then in its weakest state, and the applied testing voltage is felt more severely.

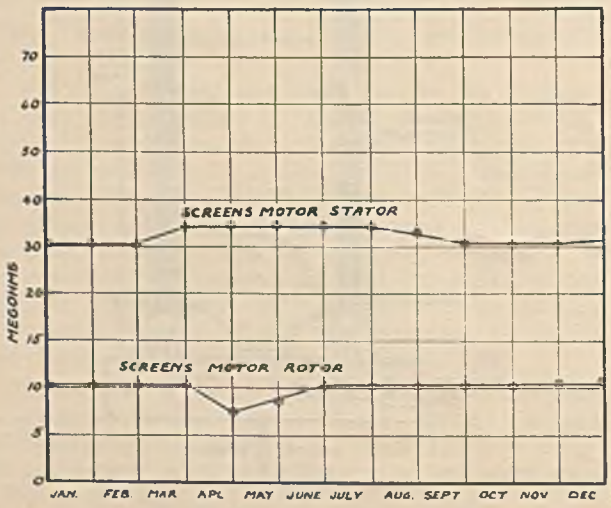


Fig. 5.—Records of Insulation Tests.

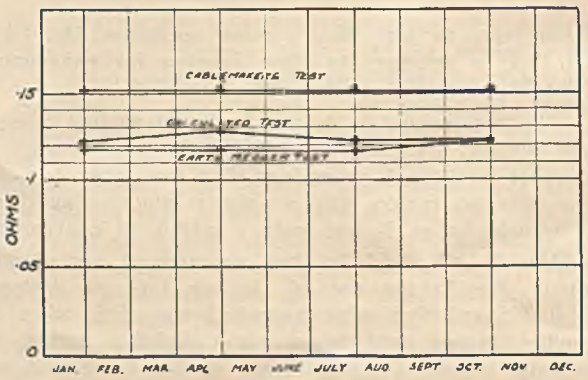


Fig. 6.—Records of Cable Armour Continuity.

Continuity test results are shewn in Fig. 6. Here are to be seen proofs of certain points stated earlier in the paper. The cable makers' figure is seen as a constant reading, whilst the Earth Tester figure shews a slight variation which can be explained by the reason that the tests were made by different individuals. The calculated figures also shew variations, possibly due to contact resistance or a slight voltage drop in the testing battery. The cable under test has a duplicate which is bonded by metal-clad gear, hence the improved armour conductivity. It may sound paradoxical but the nearer the test result get to the cable makers' figure, the more precarious is the armouring condition becoming.

Graphical records are to be preferred to sheet and book logging. They give a concise and clear retrospective view and do not lend themselves to the folly of over-logging.

DESIGN AND BONDING.

Switchgear.

It is not always certain that a fault on any part of gear is the same as it was originally. A large proportion of faults originate as earth leakages and in time develop into more serious dimensions. In this respect the author would respectfully suggest that there is a tendency on the part of designers and makers of present day switchgear to cramp and make complicated the interior of switchgear in the effort to embody features such as contactor control, fool proof and emergency arrangements, and other such devices. Whilst appreciating what has been done to improve the external details of casing and metal frame-work design, one looks upon the multiplication of leads and wires into places of limited space as a step in the wrong direction. Instances can be cited where leads of different potential, subject to the ill effects of oil and oil vapour spray, dampness and dirt, touch and cross each other being separated only by the insulation. All is well as long as the insulation plays its part, and does not become deteriorated or subject to cracks and damage during examination and cleaning. If it is necessary in the case of transformers, that care should be taken to guard against danger by reason of the lower pressure apparatus becoming charged above its normal pressure it is surely also of importance that equal precautions should be taken in the case of contactor gear and all other apparatus which has a composite nature.

It is the practice with some makers in the case of small power motor switchgear to combine the stator switch and rotor resistance in the same unit. Would it not be safer to separate these circuits of different potential? The construction of these details necessitates uninsulated parts and there is always the risk of the lower pressure windings becoming charged by the higher pressure apparatus, causing faults and short circuits to earth. When it is necessary to combine circuits of varying voltages in the same unit, it should be the aim of the designer to confine the parts to separate chambers and to place an earthed metallic barrier between them to protect against trouble caused by loose wires and broken connections. Economies in structure of gear may have their origin in the desire to cut down first cost, but to the engineer, who has the interest of reliability uppermost, the first consideration he demands is that the gear which has the best reputation as a working unit is always preferable to that which is cheap and full of unforseen pitfalls for the maintenance electrician.

Motors.

It would be difficult to make hard and fast rules for the selection of motors for mining purposes. It can be safely assumed that the totally enclosed motor is the least subject to earth leakage trouble.

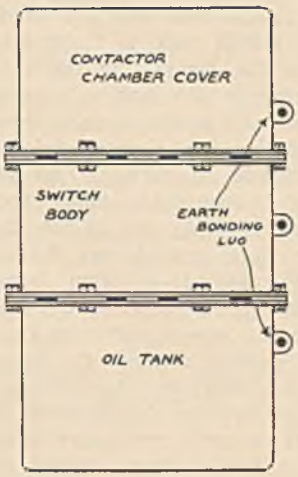


Fig. 7.—Contactor.

Sealing Boxes.

It is pleasing to note the great progress made in the effort to connect lead covered cables to motors, switchgear and other apparatus by means of the mechanical plumb joint. By this method the insulation can be preserved, continuity of lead cover maintained and a sound practical job made of the connection of the armour by glands to the sealing boxes. The possibility of making armour connection to apparatus at the surface ready for use underground will be looked upon as a very great advantage and will certainly receive wide application. The importance of the armour glands cannot be overestimated, they should have a gripping or biting connection over their whole surface. The use of metal wool or foil is to be deprecated.

Joint Boxes.

Castings of joint boxes should be of ample dimensions with respect to conductivity. Joint boxes should always be mounted on insulators, acting as spacing pieces, this method serves for passing a current of air around the box and safeguards the metal from corrosion caused by dampness and electrolytic action when in the vicinity of water with salt content.

Bonding.

There is always the chance of discrepancies creeping in when alterations are made in design meant to further the practice of new principles. Fig. 7 illustrates a flame-proof contactor unit. Following the intention of the designers, there is a space between the body of the

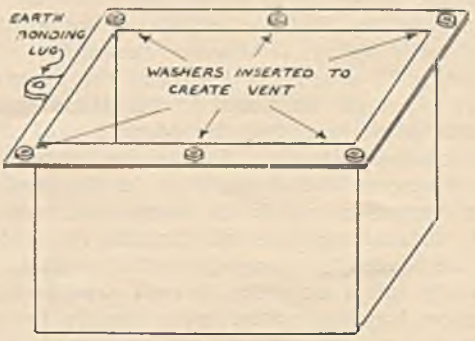


Fig. 8.—Flame-proof Tank with Earth Lug as part of the casting.

unit and the switch tank and the conductivity between the body and switch tank is maintained by a number of rivets along the flange. In the case of a fault to earth taking place in the tank or for that matter in the contactor chamber, it is questionable whether the meagre contact offered by the rivets would be sufficient to convey a discharge to earth in an adequate manner. Rarely are switch covers and tanks supplied with bonding connections, yet they are in the danger zone, even when larger surface contacts are furnished by the use of washers (Fig. 8). It is often found that they are affected by oil vapour and dust, sufficient to render them of unreliable service. It may be argued that the bolts or studs passing through the flanges should maintain a good connection; but the holes are usually drilled without any consideration for tightness of fit, and, what is more, to act as earth connectors is not their primary purpose. The Memorandum strictly states that earth bonds and connections should have a primary importance and the earthing of the installation not be dependant upon bolts which serve some other purpose. To avoid simply depending on flange contact made between parts of apparatus for bonding purposes, makers have adopted special means of terminal connection; studs and clamps are amongst the methods used. Drilling and tapping holes in castings weakens the structure and in the case of covers and tanks it would be contrary to the principles of construction.

To instal a device for making it impossible to start a motor unless it is earthed would bring about an ideal condition, but there are inherent difficulties and complications which make it a difficult problem It is the author's opinion that a definite ruling should be made with a view to ensuring that parts of apparatus must be provided with earth bonding connections. He would suggest that all parts of castings casings and framework should have as part of their structure, earthing lugs, cast to a uniform size, protected from the possibility of fracture, accepted by all makers as a standard for universal application. This would help in making the earth bonding system a matter of real primary importance acknowledged by maker and user alike. Metal-clad gear makes for a simple general arrangement: it avoids accumulation of dirt and when of robust design is a sound engineering job. It offers useful service in bonding in the sense that it can be made an integral part of the earthing system. To depend upon metallic coverings of this kind, in the hope of dissipating a charge of electrical current due to leakage, by its casual contact to earthed structures, pipe lines, girders and other metalwork is not good practice, neither is it in keeping with the spirit of the Coal Mines Regulations.

LIGHTING.

Strange to say, it is on circuits where the potential difference is low that we experience the most trouble due to earth leakage. Although the supply of current for lighting is usually at less than the stipulated low pressure maximum mentioned in the Mines Regulations, one must never overlook the possibility of danger in circuits of low potential. For mining purposes only a system having metal-clad coverings, lending itself to good binding purposes, should be considered. All departmental installations and all circuits included therein should be bonded to a common earthing system. To have local earth spikes or plates at each department without a common bonding system gives rise to trouble from circulating earth currents and can be likened to a power installation with an earth plate at each individual unit and no surface earth connection.

When transmission lines pass over or under privately owned circuits we have to pay them respect by installing cradles or guard wires. The same respect should be paid to our own responsibilities when wires are suspended over metal structures; likely to be a source of danger if subject to a leakage of electricity. There is much to be said for distribution by armoured cables in the ground, or cables suspended on an earthed wire carrier, it gives a sense of protection and permanency to the system which cannot be claimed for unguarded transmission wires.

Portable lamps and other apparatus should always be connected to the system by trailing cables having a metal covering for earthing purposes. This will be very much more effective than the inclusion of a special earth core for use in winder drums or boilers, where there is always the chance of cable fracture by falling matter or misuse of tools.

It must be recognised that there have been great strides of advancement made in metal-clad lighting systems of recent years, but it must not be forgotten that the most effective evidence in favour of underground face lighting will be the assurance of safety than can be given by surface lighting experience. All lighting circuits should have a leakage indicator, preferably a lamp indicator; the sense of alarm is greater with a continuously reflecting lamp than with a meter indicator.

The most recent lighting problem introduced into mining work is that of wiring pithead baths. These buildings are subject to regular and rapid changes of temperature, resulting in great stress being placed upon the metallic coverings and the enclosed wires. Condensation takes place and there is continuous trouble with leakages. Ordinary wiring such as galvanised and enamelled conduit, with V.I.R. cable rapidly deteriorates and in this fact lies the problem for makers of lighting systems. Any colliery with a future of 15 years, has the necessary qualification to a State-aided bath; that being so, the innovation is likely to prove popular and its electrical equipment worth while studying.

CIRCULAR NO. 23.

The instruction issued by the Mines Department, and included in the recent publication of the Regulations, which indicate that all outgoing feeders should be earthed before they can be worked upon, has set switchgear makers and maintenance electricians thinking and working out plans for complying with this important ruling. The spirit of the law is excellent, but to put the requirement into practice is a very complicated matter. On ring mains or duplicate feeders there is always the question of the other end of the main or feeder to be discharged. Serious damage to apparatus and loss of life can easily result by misunderstanding in the procedure of discharging mains and feeders connected to common busbars, and it can only be when there is absolute supervision in operating the earthing gear at both ends that safety will be assured. Switchgear makers have their own particular methods for providing means for discharge of apparatus. Some employ jumper connections, others rely on plug fittings. It will be a very costly addition to provide for different makes of switchgear. Perhaps it is not too much to hope that all switchgear makers will adopt a uniform method of construction for discharging gear, some reliable method and one not too costly.

The ultimate factors which determine the severity of the stress caused by a fault, are the power available and the current which flows. Earthing the neutral point

stabilises the system, limits the potential to earth on the line conductors and gives scope for better fault protective systems. Since energy is the product of power and time, a good earth connection offering a quick and reliable dissipation of the leakage current, will tend to eliminate the time factor, thus greatly assisting to reduce the amount of fault current on an earth short.

The use of resistances or reactance in the neutral point circuit to limit the fault current depends upon the size and condition of the system under consideration. On a system which is heavily bonded, equipped with a well maintained earth connection allied to a sensitive leakage protective device, it is reasonable to assume that to earth the neutral point solid will provide ample assurance of safe working.

It must not be expected that a good earth connection will end all troubles, but its contribution to protection cannot be over-emphasised. In the coal mining industry today we have experts in most branches, the proposition of an earthing engineer is well worth considering, especially where there are groups of collieries. The subject of earthing is a very wide one and to become expert in it, necessitates a special study. Earthing from the viewpoint of chemistry, geology and other sciences, methods of earthing, leakage protection devices, tests and test records are just a few of the phases of earthing as applied to electrical engineering. A knowledge of what is good and bad in the subject here discussed has a great commercial value, particularly when it is realised that the majority of accidents both to human beings and apparatus can be attributed to some defect in the earthing system.

In conclusion, the author would like to thank the principals of the Ocean Coal Company for permission to read this paper, and their kindly interest in its preparation.

AYRSHIRE SUB-BRANCH.

At a meeting of the Ayrshire Sub-Branch held in the Lesser Town Hall, Cumnock, on Saturday, 13th December, Mr. James Garven, the Branch Chairman, presided over a large attendance which included many coalcutter operators of the district.

Mr. Alex. McPhail read the following paper.

Short Circuits to Earth with Notes on Coalcutters and Gate-End Boxes.

ALEX. McPHAIL.

Short circuits to earth are always dangerous unless under certain conditions, and these conditions are essential for the safety of life, and also the running of the plant successfully. In all completely insulated systems, short circuits to earth are dangerous unless good earths and good conductivity of the armouring of the system is maintained, and these are very often subject to neglect. Joint boxes ought to be installed with the greatest care, and also the bonding, so that the proper conductivity is maintained at these points in the circuit. These ought to be tested when installed for conductivity, and tested also at regular intervals, unless complete soldering of the armouring across these boxes is done when installed, or some other mechanical means used to bond the ends of the armouring other than the system of bonds usually adopted.

The next thing of importance is the earth plates themselves; these should be tested and maintained at about two ohms to earth by increasing the earth plates until this is reached. When this takes place a short circuit to earth will be quite safe and the frames of machines and armouring will be kept at earth potential.

To prevent short circuits to earth the insulation and cleanliness of the machines has to be maintained and this can only be done by looking after the details, which means regular examination. By these examinations defects can usually be seen before a short circuit can take place. Fuse boxes should be scrapped and trip switch installed, especially in three-phase work, as these are always a source of danger, because fuses are never properly put in and phases are thereby upset, which means out of balance currents with a number of motors stopped by tripping—"all for the want of a horse shoe nail."

When fuses cut out there is usually a short circuit to the side of the box, because of fuse holders being broken by careless workmen not inserting asbestos tubes or cleaning fuse holder of copper by last fuse before inserting new wire. All these details go to cause short circuits. Remember that a short circuit to earth causes a number of others through the potential rising above earth at the moment, causing a swige or a strain on the insulation of the system. The argument put forth, that, with the neutral point of the system insulated, there is less danger from shock to anyone coming accidentally in contact with one pole of the system, is not true. Since the effect of capacity is to keep the neutral point at earth potential, the shock would be the same. The only safe way for a three-phase system is to earth the neutral point; you will then have a complete short circuit when an earth takes place, which will trip fuses or switches. The demonstrations will shew the effect of what I have said. The effect is as you see, with a short circuit on an insulated system, and that it is not revolving round the neutral but some other point (which may be dangerous) with regard to the relative positions to earth of other points of the system.

Coalcutter Motors.

A.C. motors are non-synchronous motors, and an induction motor is a kind of a.c. current transformer. The stator or fixed portion has the primary winding and the rotor has the secondary winding. There is usually not so much starting apparatus in a.c. work as in d.c. work; the a.c. starting apparatus having at the most two steps, a limit which does not call for so much care on the part of the operator; in the newer form of a.c. coalcutting machines only one step, direct on to the mains, is used, because nearly all the coalcutter motors are squirrel cage motors. With a three-phase squirrel cage motor to hold the rotor so that it cannot revolve, is to produce in effect a short circuited transformer. Thus the stalled machine, if connected across the supply mains, would take a large current into the primary winding, this in turn would induce heavy currents in the rotor bars. The primary current would be not more than about from three to four times the full load current; so it is a good feature of the induction motor that the current is automatically limited.

The heavy currents taken by short circuited motors would not be so objectionable if the power factor were not so low. The power factor of a circuit depends upon the relative value of its resistance and inductance. If we could have a circuit which was all inductance and no resistance, the power factor would be zero. And conconversely if we could have a circuit which was all resistance and no inductance, the power factor would

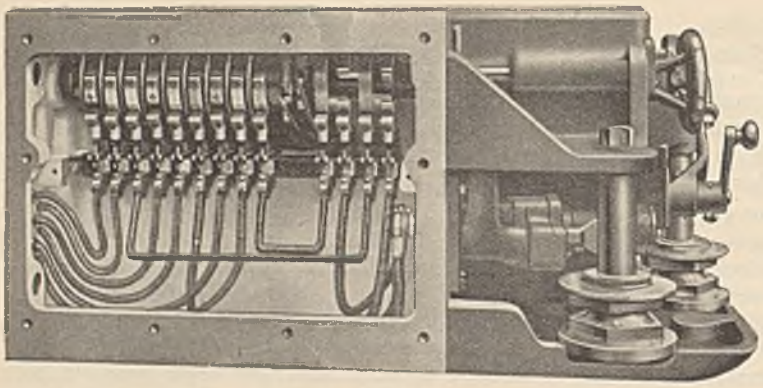


Fig. 1.—The Anderson-Boyes Coalcutter Starting Switch.

be unity. It is because the resistance of a short circuited rotor is so low and its inductance so high the power factor at starting is so low. Only that portion of the current which employed in overcoming resistance is useful or "power" current, and the rest is useless or "wattless" current because it is right out of phase, i.e., lagging 90 degrees behind the e.m.f. When the motor is running the back e.m.f. acts as a resistance, so that the power factor is improving all the time the motor is speeding up, and is highest when running at full speed. The low rotor resistance is then an advantage because it reduces the heating losses to a minimum and give the motor a high efficiency.

Switches should have a protecting insulation inside the box to prevent an arc from the switch or fuses shorting to the side of the box. This is one of the greatest sources of trouble the author knows of, and he has definitely traced about 90 per cent. of punctures to these boxes. All switches, fuses, and starter boxes should be lined with some insulating material that will not burn and which can be readily removed for cleaning: also insulation barrier should be placed between starter fingers to prevent the insulating bushes from being burned. These linings and barriers can be arranged quite easily, and they should be inserted before installing any electrical apparatus; it will save time, expense and worry. The cost is very little to prevent so much damage.

Coalcutter Starter and Mining Plug.

At the conclusion of his paper Mr. McPhail said that Mr. W. F. Anderson, of Messrs. Anderson & Boyes, had come along at his invitation to demonstrate one or two of the pieces of apparatus he had mentioned. Mr. Anderson then exhibited and explained a Starting Switch for an Anderson-Boyes a.c. chain coalcutter and also an improved mining type Plug and Socket.

With a Star Delta Starter of this type, said Mr. Anderson, the fluctuations in amperage and voltage are less marked and more easily accommodated in circuit breakers than where direct switching on to the line is adopted. It has been designed specially for coalcutter work and is of ample current carrying capacity. The switch barrel is of special construction, being built on the unit principle with insulating rings between each contact, thus preventing arcing between contacts and providing reliability under the adverse conditions of repeated switching to which a coalcutter is often sub-subjected. The finger tips and barrel contacts are of ample section, are renewable, and are arranged with sufficient pressure to ensure perfect contact. A reversing switch is mounted in alignment with the starter and is interlocked with it. This is of the same robust construction as the starter. A reversing switch is an important feature in a coalcutter because, under certain conditions, the reversal of the machine is fairly frequent. With a dependable reversing switch time is thus saved and the dangers of improper earthing or unsafe handling of a live plug is guarded against.

The other example of equipment exhibited was an Anderson-Boyes B.E.S.A. Plug and Socket. This plug and socket, said Mr. Anderson, is manufactured in accordance with the British Engineering Standards Specification No. 279—1927. It is of 100 amperes capacity, is of flameproof construction and complies with the Coal Mines Act and the General Regulations regarding the installation and use of electricity in Mines where Rule 132 applies. The Anderson-Boyes B.E.S.A. plugs fit any make of socket pertaining to this type.

The plug and socket is specially suitable for use on portable apparatus and can be arranged for a.c. or d.c or for special systems such as remote control or earth circuit protection.

When assembled the plug is secured by a retaining device. This device is arranged to provide means of interlocking the plug in the socket and prevents the plug from being inserted or withdrawn unless when the switch is in the "off" position. The plug is provided with a visible earth connection and the construction is such that the earth circuit is first to be made when the plug is inserted and last to be broken on withdrawal. It is of the non-reversible type, thus requiring portable machines, which require to be reversed, to be provided with a reversing switch. The operating and retaining device is integral with the socket and is operated by means of a wing nut. This device is used to move the plug into position and also to retain it there. Withdrawal of the plug from the socket is obtained by the same means. Force should not be resorted to. The insulation used is tough, non-ignitible and non-hygroscopic.

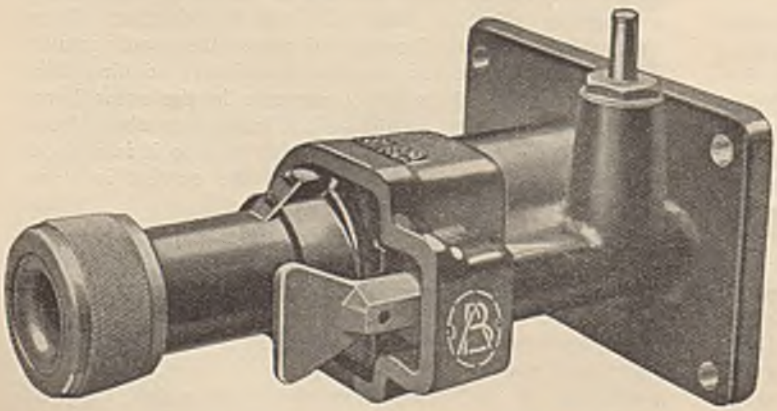


Fig. 2.—The Anderson-Boyes Mining Plug and Socket.

Discussion.

An interesting discussion followed the demonstration and a number of pointed questions were asked, most of them by coalcutter operators present. The more important were dealt with as follows:

Are there any means provided in the A.-B. B.E.S.A. plug to prevent it being withdrawn from a machine if the current is still on at the gate-end box?

When used with ordinary overload circuit breakers, if the coalcutter switch is "off" the plug can be withdrawn. The plug, however, is arranged to work in conjunction with an earth circuit protection system, and where this system is adopted the switch at the gate-end is automatically tripped when the plug is withdrawn. This can be arranged for, where required.

Are there any means provided to prevent dirt entering the plug or socket when these are separate?

A cap can be provided for fixing over the contact pins in the socket, and one for fitting on the end of the plug. These parts, however, are only supplied when required.

Since the plug is non-reversible, what would happen if on going to start up a shaker conveyor it was found that, through cables being extended during the night, the motor was running reversed?

The electrician would require to reverse the connections.

The enquirer works an Anderson-Boyes chain coalcutter and the floor is soft. He has sometimes to flit jib first and has considerable difficulty. Does Mr. Anderson think that a base plate extending below the cutting chain would be an advantage?

Under such circumstances a base plate extending the full length of the machine would be a considerable advantage.

Is there any disadvantage working with a bottom plate on the machine if the pavement is hard?

This is not detrimental to the working of the machine. Without a bottom plate and on a hard floor the machine cuts at floor level. If the floor is rock, a base plate is an advantage as it prevents the picks striking the rock.

The enquirer was working a machine and it stalled: he cleared the cutting chain and pinched the machine back about 6 inches. On switching on, the motor only hummed and blew a fuse. A new fuse was put in and the same thing happened. On putting in a third fuse the machine started up. Could Mr. Anderson say what was the cause of this?

Assuming the cutting chain to be clear, the machine appears to have been on two phases only, probably due to a finger on the switch being jammed, or a bad connection in the gate-end box. When the finger cleared or the fault in the gate-end box was rectified through renewing fuses the machine being again on three phases would be expected to start up.

We are not allowed to go into the coalcutter switch box, and how could we rectify a fault if it occurred here?

That would be a job for an authorised person and not for a machine operator, the only course open would be to send for the authorised person.

On the motion of Mr. Dugald Baird, vice-president, cordial vote of thanks was passed to Mr. McPhail for his paper and to Mr. Anderson for bringing along the apparatus and demonstrating it.

The Secretary, Mr. J. C. MacCallum, intimated that a new member, Mr. James Lorimer, had joined the branch.

Through the generosity of Mr. Baird, vice-president, the members were afterwards entertained to tea.

YORKSHIRE BRANCH.

Annual Dinner.

The Second Annual Dinner of this branch was held at the Exchange Restaurant, Sheffield, on the 28th February last. Fifty-six members and friends were present, the guests of the evening including Mr. E. H. Frazer, H.M. Inspector of Mines, Yorkshire Area; Mr. G. P. Henzell, Generation Superintendent, The Yorkshire Electric Power Co.; Mr. W. E. Burnand, Chairman of the Sheffield Sub-Centre of the Institution of Electrical Engineers; and Mr. W. Jackson, President of the Yorkshire Colliery Undermanagers' Association.

Musical interludes were admirably executed by Messrs. E. Bowling, Comedian, and W. H. Vance, Bass Vocalist.

Mr. E. H. FRAZER, H.M. Inspector of Mines, said he appreciated the honour of being selected to propose the toast of "The Association of Mining Electrical Engineers." Electricity as a rapidly growing power in the land meant that the electrical industry was one of the few industries which enjoyed prosperity at the present time.

Whilst Electricity is produced from coal and also to some extent from water power, Mr. Frazer believed that coal would continue to be the chief source of electrical power in this country. The cycle of operations of the mining electrical engineer was to produce coal to produce electricity to produce coal, and so on.

The extent of the electrical equipment in mines was shewn in Mr. Horsley's report—there were approximately one and a quarter million of horse power electrical machines in mines. A great total: and they, as mining electrical engineers, were responsible for the huge mass of machinery engaged in that work. Mr. Frazer had been making a little calculation and learned that if all the coalcutters in use at the present time were piled one on top of another they would probably—topple over. Another little calculation which he had made was that if all the cables were strung out into one long line, they would probably reach all round this island of ours, and the remainder to spare would get into an awful tangle.

Mr. Frazer then referred to his search for a suitable definition of the mining electrical engineer. He had, as one result, been led to compiling a modern version of a popular nursery rhyme:—

"This is the man, all haggard and worn,
"Who works in the mine all day and all morn,
"And oft from the afternoon right to the dawn,
"To produce the juice, to hole the coal,
to feed the fires,
"That burn in the house of John Citizen."

Knowing then what a mining electrical engineer really is, it would be interesting to refer to his status, as defined by the Mines Act. Responsible duties were laid upon the deputies, but nothing, or next to nothing, upon the mining electrical engineer or the ordinary electrician. That legal position did not, of course, accord with practical fact. Mining electrical engineers are very important persons at the mines, but so far legislation did not appear to have recognised them.

When dealing with the duties will come the question what are the qualifications of a mining electrical engineer? Any Tom, Dick, or Harry can call himself a mining electrical engineer. A man can get a job at a mine on a coalcutter and after one week he leaves and

goes to another, where he gets a job as an experienced coalcutter operator. After a further week, he becomes an experienced electrician, and with the next step he is an experienced mining electrical engineer.

When the duties are defined by law, there will be some examination to pass and in that Mr. Frazer said he thought the Association could render great help, not only in helping legislation to define what are the duties of electrical engineers and electricians, but also in defining what shall be the qualifications of electrical engineers, and how those qualifications shall be tested. That, he believed, was a duty which would be put upon the Association.

At present, the mechanical and electrical engineer had only to locate any trouble that existed and report it to the manager. He has no duty, by law, to keep the machinery right or wrong. Surely, they would all recognise and agree that that was not a proper thing. It should be laid upon electricians not only to see whether it was right or wrong, but to keep it right.

Continuing, Mr. Frazer said the colliery manager could not pretend to have an expert knowledge of electricity. He was a sort of administrative man, who had to be responsible for everything. The electrician only looked after his little corner and, at present, was not even responsible for that. Mr. Frazer presumed that one of the chief things the Association endeavoured to do was to improve the status of electricians and electrical engineers, and possibly by legislation. To do that it would be necessary to give expert evidence and place knowledge before Committee ; later on when it had been decided to set up Committees.

Mr. Frazer said he was not quite sure whether he ought to suggest that the Association could render most assistance by gathering into its fold practically all who had any connection with mining electrical work. Of course, with the greater status which would accrue to mining electrical engineers would come greater responsibility : and there was the chance that they would sometimes share "the dock" with the colliery manager.

Mr. Frazer said he considered the best looked-after part of the colliery, and he was sure Mr. Horsley would support him in this view, was the electrical equipment. He was a little jealous, or perhaps envious, of the money that was spent on electrical plant : He would like to see more money spent on things like steel props and girders. He had the feeling that some of the money was, so to speak, now spent simply in "gilding the lily."

None but an expert could criticise the present arrangements in the mine. Four additional Electrical Inspectors of Mines had recently been appointed to harass the mining electrical engineers. Notwithstanding the new additions to the staff, Mr. Frazer trusted they would still rub along well with the electrical men who kept the mines safe, so far as the electrical equipment was concerned. The figures published as to the number of deaths in mines each year—there were none killed by electricity last year—spoke volumes for the efficiency of the mining electrical men.

Mr. Frazer proposed the health of "The Association of Mining Electrical Engineers"—coupled with the name of Mr. Gibson, the President, against whom he had never heard of a wrong word being spoken.

Mr. J. W. GIBSON (President of the Association) said the reference by Mr. Frazer to the North East area as being more fully developed in regard to the use of electricity in mines, reminded him of the occasion, it would be 31 years ago, when he visited the Sheffield area to get particulars of some early successful attempts at electrical coalcutting. At that time, the Yorkshire district was ahead of the North East as far as electrical cutting was concerned ; but the machine Mr. Gibson saw sparked sufficiently to light the whole coal face. On that occasion, too, he was shewn one of the first electric miner's lamps.

In regard to the Association and the members' efforts, they had completed 21 years of service in the interests of mining electrical engineers, and in the interests of coal mining. Looking back over that period, Mr. Gibson unhesitatingly could claim they had done much towards helping to improve the status of mining electrical engineers and colliery electricians. A good deal of attention had been given to education and those who were able to carry off the Certificates of the Association had tangible proof that they had added theoretical knowledge to their practical attainments.

Mr. Gibson said he did not know of any mining area in any part of the world where he had not met with British trained mining engineers. There was no room today for the rule-of-thumb man. The man who had to take care of developed electrical machinery must have a thorough knowledge of what he was handling. Thirty years ago the rule-of-thumb man might have served, but today he must know his job thoroughly. No one should be inclined to give a post of responsibility to a so-called electrician who could not shew his credentials in the form of a certificate.

It was rather an interesting fact that the coming of age of the Association synchronised with the Faraday Centenary.

Referring to coalcutting affairs, Mr. Gibson said he found that development had occurred so rapidly in some parts of this country that 80% of the coal was being mined by mechanical means. They were often told that they should develop the collieries—mechanise and electrify them up to the standard in other countries. Many areas in this country were ahead of those districts abroad with which they were so often adversely compared.

In conclusion, Mr. Gibson urged all the members of the Association present to increase the membership roll, because the longer the membership roll—the better the opportunities and the stronger the influence with which the Association could pursue its beneficial work. He thanked Mr. Frazer and all present for the hearty way in which they had honoured the toast of the Association.

Mr. H. WATSON SMITH proposed the toast "Our Guests" coupled with the name of Mr. Henzell. Having mildly protested that the Yorkshire Electric Power Company (as represented by Mr. Henzell) should not go round about the country giving away their power (as they called it) at a rate which did not pay them (so they said) and yet not paying a decent price for the coal which made their electricity. Mr. Watson Smith said he did seriously consider that those people who used so much of the power should receive a few shillings more for their coal. It was the selling price of coal which made the depression so hard, and the difference would mean a good deal to those who produced it.

Mr. Watson then turned to affairs of the Association generally and acknowledged the very considerable help which he received from his electrical engineer and the electricians under him. He had a very loyal band of men, and was pleased to be present on this occasion because of those of his staff who were engaged on the electrical side of the collieries.

He had followed with interest and pleasure the remarks made on the status and qualifications and positions of electrical engineers of collieries. In the interests of discipline, as well as in the interests of efficiency, he thought it was time that the electrical engineer at collieries was given some clearly defined status, instead of having to bear the responsibility, which he had now, of being under people who knew nothing at all about electro-technical work. He thought that the mining electrical engineer should be the man against whom Mr. Frazer should take proceedings, instead of the agent. The use of electricity was extending in all ways at the pits, and Mr. Watson Smith believed personally that the big benefit that was to follow would be due to the collieries making the greatest use of electricity underground.

Mr. G. P. HENZELL, responding on behalf of the guests, said he was sure of the support of all the guests, when he called this a particularly happy toast to which he had the honour of replying, because, in Yorkshire, the visitor was always made to feel so really welcome.

He thanked Mr. Watson-Smith for his kind remarks, although they rather reminded him of the story of the little Cockney who went into a cheap tea-shop and said to the waitress, "Fetch me a pot o' tea, a bit o' fish, and a kind word." After a time, the girl returned, placed the meal on the table, and was walking away when the Cockney asked "Wot abart the kind word?" The reply whispered confidentially in his ear was, "Don't eat the fish."

On one or more festive occasions during this winter Mr. Henzell had been musically and melodiously informed that there was a good time coming, but there was a proviso that it was rather a long way off. They all liked to look forward to the sunlit outlet when passing through a very long dark tunnel; they thought of the unhappy whist player who, when sorting the last cards of a very bad hand, found the Ace, King, and Queen of trumps!

Mr. Watson Smith had expressed something with which he, Mr. Henzell, had full sympathy—the present condition of the mining industry. The very rapid rate of developments had made it difficult to look ahead. Hardly has a new plant been put into use than it begins to be obsolete. The only method of extension feasible was to develop in a series of blocks or units, independent of one another.

During recent visits to various manufacturing firms in this country, Mr. Henzell had noticed tremendous progress in design and manufacture, especially during the last three years even during the trying time when industry generally was working under a very serious handicap.

Mr. J. STAFFORD submitted the toast of "Kindred Association."

He referred to Mr. Burnand, representing the Institution of Electrical Engineers; to the President of the Association, Mr. Gibson, who was also closely associated with the same Institution, and who was also a Fellow of the Institute of Fuel. Mr. Jackson represented the Yorkshire Colliery Undermanager's Association. There were also present representatives of the Mining Institution and of the Institution of Mechanical Engineers.

The necessity for so many Kindred Institutions had often set him thinking. Mr. Stafford recalled how when he was very young he took the Chair at a religious affair, at which there were present an Archdeacon of the Church of England and a President of the Congregational Union. He happened rashly to express the hope that the Church of England and the Congregational Union should be united. He was quickly and firmly informed that "Individuality is one of the greatest assets of our nation, and we must not lose that individuality."

The indispensability of Associations and Institutions might be illustrated by a story. The angels of heaven and the denizens of the other place fell out and the prince of the nether regions made a hole in the floor of heaven. The sulphorous fumes poured through and things were going pretty badly for the angels. They looked about for someone to help them and, very naturally, they decided that the situation called for a Fellow of the Institute of Fuel but, Mr. Stafford regretfully informed Mr. Gibson, there was none such to be found!

Mr. W. E. BURNAND having responded, the Chairman of the Yorkshire Branch paid to the Branch Secretary who so assiduously applied a great amount of his time and energy to the benefit of the Branch.

Mr. MAWSON (Secretary) thanked the company for their cordiality in honouring the toast of his health. Nothing gives a secretary greater satisfaction than to see his arrangements turn out successfully, and he was pleased to see so many members present. The Yorkshire Branch was in a good financial position; it already had about 180 members and it was confidently hoped that the roll would soon carry two hundred names.

SOUTH WALES BRANCH.

Mining Type Control Gear.

WILLIAM ROBERTS.

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

The author need make no apology for his choice of subject because the last report of H. M. Electrical Inspector of Mines shews that for the past ten years 32% of the fatal accidents, and 46% of the non-fatal accidents connected with the use of electricity in mines were to do with apparatus that is generally classed as switchgear. Furthermore, the records also shew that for the same period 25% of the fatal accidents happened to people classed as electricians, and a number of these accidents could possibly have been avoided. To quote from the leading article in the January issue of *The Mining Electrical Engineer*—"It is more than "disconcerting to know that there are still some men "who can be so utterly foolish as to play about with "live terminals, to put current into partially assembled "machines, to ignore deliberately the simplest obvious "measures and rules devised for their particular benefit "by plant makers and by experienced engineers and "miners."

Air-break Gear.

Within the last two years the whole question of flame-proof and explosion-proof gear has altered. To-day the problem must be looked at from a different standpoint from that of 1924, when we first talked of Sheffield Test Certificates. At that time these were regarded as the ultimate safeguards wanted by the Mines Department, and both manufacturers and users endeavoured to live up to their requirements and so satisfy what were then known to be the most stringent conditions.

A period of about two years has put those Certificates out of date because it is only within that period that investigations have finally decided upon the nature of the gases liberated when oil is vaporised by an electric arc.

In 1924 manufacturers designed gear to withstand a methane explosion the maximum force of which, under the worst conditions, is 110 lbs. per square inch, but the explosive pressure may be very much greater than this when hydrogen and acetylene, which are the two gases set free by oil disintegration, are ignited: moreover, the flame of burning hydrogen will pass through a vent that will extinguish a flame of methane.

This greater knowledge is what makes a Sheffield test of no use to-day, simply because new conditions have arisen and are established in fact to make it out of date; it is to be noted that many more certificates for air-break gear than for oil-immersed apparatus are now being granted by the Mines Department and Sheffield University.

On account of the difficulties of manufacture and the size necessary of the container, it is not practicable to design oil tanks which, while being readily accessible, will withstand internal pressures exceeding 110 lbs. per square inch, even with the most efficient means of relief, and the solution of the problem as accepted by many manufacturers is to cut out oil completely and go in for air-break only. Thus this matter has been carried back once again to the 1924 conditions, accepting the methane mixtures as the most destructive forces to be contended with, and which, of course, can be provided for in the various enclosures.

The theory that a piece of oil-immersed gear is in itself flame-proof is not now accepted; on the contrary, such gear must be enclosed in a case designed to withstand very considerable pressures and to prevent the causing of an external explosion. Correctly designed air-break gear will operate satisfactorily under the most severe conditions, while the enclosure is much simpler to construct, and the maintenance much easier on account of the clean design possible with consequent accessibility.

A number of manufacturers have for the past four years taken steps to meet these altered conditions, and all the illustrations to be shewn with this paper are of modern colliery air-break apparatus.

In addition to starters and controllers, which have been developed for some time as air-break gear, many firms are now devoting themselves to air-break switches for feeder work, as experience shews that less maintenance is required with well designed air-break gear. The U.S.A. are far ahead of us in this practice, they having built air-break circuit breakers which have repeatedly broken 15,000 amps. at 20,000 volts.

General Construction.

Apart from the question of flame-proof enclosure it has also within the past few years been generally recognised that the practice of merely modifying standard apparatus for colliery use is wrong, and that mechanical and other conditions necessitate an entirely fresh design for colliery gear, even though flame-proof enclosure may not be called for.

One of the fatal accidents reported by Mr. Horsley (H.M. Electrical Inspector) in his last report would appear to have been directly attributable to the use of industrial type gear, whereon the fastenings of a switch oil tank worked loose, and caused the death of a motor man who had apparently tried to hold up the tank as it fell.

It will be realised as necessary by anyone who has worked on a colliery, that whatever the internal construction of the gear may be, it is absolutely necessary for it to be much more robust so far as concerns external parts, such as, cases, handles, doors, etc., than what will suffice for an ordinary industrial lay-out.

The general construction of mining type gear even for surface work is a heavy boilerplate casing, with substantial cast-iron or sheet-steel covers and packed grooved joints to render it dust-tight or water-proof as the case may be. The important difference between ordinary mining gear and flame-proof gear apart from the construction, is the fact that flame-proof gear should always have a separate terminal chamber in which incoming and outgoing cables are connected; the manufacturers takes suitable stems into the flame-proof enclosure so that there is no need for the colliery engineer on site to have to make any connections that necessitate the opening up of the flame-proof portion of the apparatus.

Functions.

The essential functions of any control gear are that it should do its job with complete safety to (1) The motor being controlled ; (2) The supply mains ; (3) The operator ; and it can furthermore be stated, as a general rule, that the correct time to take to start up any motor, is the least time in which it can be done, consistent with not exceeding a given pre-determined maximum current.

Loads.

The author considers it would here be worth while to summarise the starting characteristics of the various types of motors generally employed, and directly from the point of view of the control gear. The essential consideration is the type of load, and it would be just as well to set this out clearly. Loads can really be classed into five categories, which in order of severity are as follows :—

(1) No Load.—The torque practically zero. Motor uncoupled, or on to a loose pulley.

(2) Dynamo Duty.—Torque varies directly as the speed. A motor generator set is typical of this load.

(3) Fan Duty.—Torque varies as the square of the speed. A medium speed light fan, or a centrifugal pump would come into this class.

(4) Brake Duty.—Torque constant. A three-throw pump or a rope brake would cover this.

(5) Flywheel Load.—Torque maximum at starting. A mortar pan or a machine with a heavy flywheel would come into this class.

It will be appreciated that in some cases the weight or size of a special piece of apparatus will place it in a different category from that given above, e.g., a large ventilating fan on account of the accelerating torque, as well as the running torque at various speeds would probably be in class (5), so light fans only are shewn in category (3).

Table No. 1 sets out clearly the average performance of the various types of motors when used with the types of starter specified. The simplest motor is the squirrel-cage machine, and the simplest starter for use with this is a three-pole switch throwing it straight on to the line. As will be seen from the Table, the current peak will be about six times normal, and the torque developed is normal full load torque. There is

TABLE I.

THREE-PHASE MOTORS.

Method of Starting.	Type of Motor	Equivalent Tapping expressed as % Line Volts.	Line Currents expressed as %	% of Full Load Torque.
Direct	Standard Squirrel Cage	100	600	100
	High Torque	100	300	200
Star Delta	Standard Squirrel Cage	58	200	33
	High Torque	58	100	66
Stator Resistance	Standard Squirrel Cage	50	300	25
Auto-Transformer	Standard Squirrel Cage	40	96	16
	" "	60	216	36
	" "	75	338	56
	High Torque	60	108	72
	" "	75	168	112
Slipring	Standard	According	80	50
	Wound Rotor	to	100	75
		Resistance	125	100

no inherent objection to starting the largest type of motors in this way; for example, machines up to 150 h.p. are switched straight on in the Powell Duffryn installation.

If it be desired to limit the heavy current rush at starting, the next simplest type is a star delta starter. Because this has no resistance it can be used as frequently as desired without any damage of over-heating. It groups the winding of the machine in the two ways indicated by its name, and gives a reduced voltage of approximately 58% of the normal voltage in the star position. This reduced voltage, of course, limits the torque, which is proportional to the square of the voltage applied, and therefore the maximum torque for which a star delta starter is suitable is about one-third of normal full load torque. It is quite useless employing this type of starter if worse conditions are to be met, the motor will not move.

The next type available is a stator resistance starter, which has a graduated resistance inserted between the line and the motor and which is cut out step by step as in the case of a d.c. machine. The starting conditions, however, are very poor, and although electrically it is a very good job, it is not very often employed for any but the smallest machines. It can be designed to limit definitely the current taken but, as mentioned above, any reduction in the voltage greatly reduces the starting torque.

An auto transformer starter has the advantage over a star delta starter, that three tappings are usually provided, and therefore if one is not suitable, either of the others can be used. However, it compares unfavourably with a star delta starter in first cost, and also in the danger of damage due to over-heating caused by insufficient cooling time between starts.

The starting performance for all squirrel-cage machines can be greatly improved by using a high torque motor. Different manufacturers have different names for this machine, but the essential principle is that the squirrel-cage motor has a double winding, or has some such means for introducing a high resistance at starting; this, as will be seen from the chart, gives starting characteristics almost like a slipring motor but retaining the simple robust construction of the squirrel-cage machines.

The best starting characteristics are provided by a slipring motor, wherein a resistance can be put in the rotor circuit, and gradually cut out as the motor comes up to speed. As can be seen, very high starting torques can be obtained with very little more than normal full load current from the lines. The disadvantage is that the motor itself is not quite so reliable as a motor with a solid rotor, and the machine and starter cost more money. If speed regulation is required, however, there has until quite recently been no other choice, though, within the last few months induction controllers have been successfully used for giving speed control of squirrel-cage motors and they are proving an excellent manner of controlling any motor which requires to be frequently started and stopped. The primary and the secondary windings are spaced in the carcass, and the rotor is very robust comprising only laminations. Depending upon the position which the rotor takes in relation to the primary and secondary windings, an infinite range of speed control is obtainable. The apparatus is very solid, and could most easily be compared with a transformer having an infinite range of secondary tappings from zero to the full voltage of the primary winding.

D.C. Gear.

Although it is the custom to assume that d.c. apparatus is going out of fashion, there is still a large amount of it being absorbed, and it would be just as well to touch briefly upon the special features of modern design in this respect. In general it is safe to say that there is no drive upon a colliery where it is permissible to use an ordinary faceplate d.c. starter as, even if the duty is electrically within the rating of the starter, it is nearly always certain that the operation of the starter is in such rough hands as to make it sure of being misused.

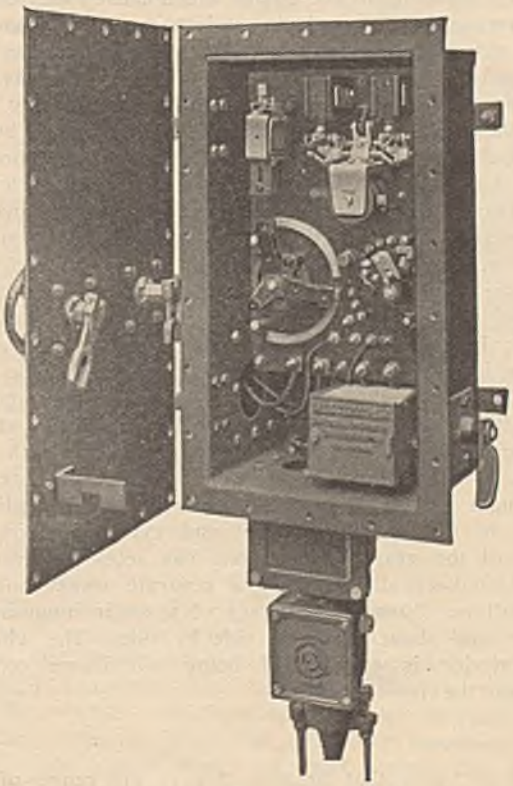


Fig. 1.

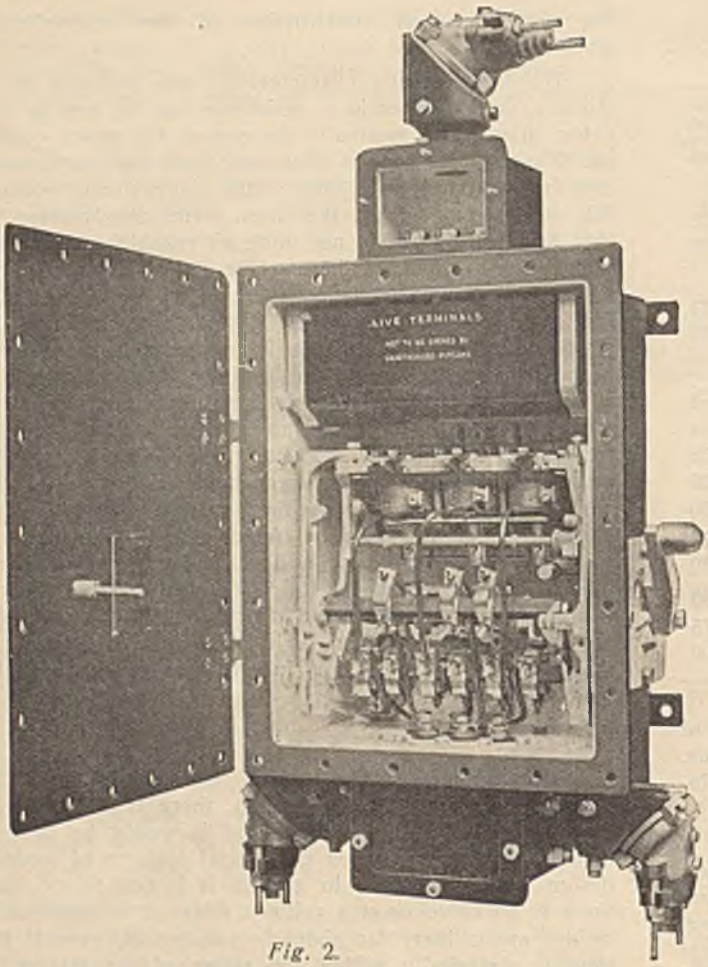


Fig. 2.

The definite weakness of a faceplate starter is that while it is a good "starter" it is a bad "stopper." It is the breaking of the circuit which causes such destructive arcing on the contacts, and to meet this condition, it is necessary to consider a heavy duty starter with interlocked contactor (Fig. 1). Roller contacts give greater robustness and stand up to the heavy duty, and the resistance is usually one-minute rated, but the essential difference is that the circuit making and breaking are taken off the starter front on to the single pole contactor. An important advantage is that the overload is operative when starting up as well as in the running position, and whether the circuit is interrupted by a backward movement of the handle, or an overload, or a stop push button, or the isolating switch, the main circuit is always broken on the contactor. No spring return is fitted, so that adequate pressure can be maintained between the moving arm and the fixed contact. The illustration, Fig. 1, shews one of these starters arranged in a flame-proof casing complete with cable boxes. An interlock is provided between the cover and the main double pole isolating switch. Protection is given to the isolating switch and even with the door open all the gear to which one has access is dead, the live terminals all being in a separate compartment at the bottom. Note the economy of space in mounting the starter and shunt regulator side by side. The whole of the interior is capable of being withdrawn complete through the front opening.

A.C. Starters.

It is likely that because this is the range of gear now most generally employed, it is also the range that shews the greatest improvements. There is now on the market a complete range of gear in which the isolating switch is part and parcel of the gear, instead of being an afterthought. The author does not consider that this design is in point of time very far ahead of Home Office requirements insisting upon this feature. The alternative of a plain starter that necessitates the shutting down of a complete section of the plant when any adjustment is wanted is bad, and the subsequent addition of a three-pole switch does does not make it any better on account of the absence of interlock. The range of gear shewn, see Fig. 2, has the isolating switch interlocked with the front door, which cannot be opened when the switch is alive, nor can the panel be made alive when the door is once opened. Even when the door is swung clear all the apparatus to which one has easy access is dead, the live contacts being in a separate sealed compartment at the top. This type of apparatus covers a complete range of all a.c. starters from the smallest to the largest size.

On most makes of starter, even of the fixed handle variety, time lags are desirable, as during the starting period the overload armatures are pulled in and generally there is no means of getting them out again. On the range of starters under discussion time lags, so far as their functioning during starting is concerned, are quite unnecessary, because so long as the starter handle is being held the overloads are restrained from operating, and the last movement of the starter handle is designed to reset the overload armatures even if these should have tended to function during the starting peak.

A further special feature of this range of gear is that during starting the iron plunger of the overloads is out of the coil, and in this position, due to the bad iron circuit, it needs a much greater current on the coil to exert the necessary pull on the overload armatures. For example, with the coil in the normal running position set at 15 amps., probably 30 amps. could safely be passed during starting with the iron core dropped, without the overload trips operating. These cores are lifted mechanically by the last movement of the handle, just as the overload plungers are reset.

A most radical departure in this range is the use of series trips for all protective purposes. This does away with the thousands of yards of No. 40 gauge copper wire which is such a nuisance when connected across 500 volts. Three substantial coils, one in each phase, carrying the main current are used, and these are entirely safe because it is difficult if not impossible to burn them out. They serve the double purpose of overload and no-volt trips or, more correctly, no-current trips. They are suitable for use with all types of induction motor, as they are rated to hold in at the magnetising current of the motor, irrespective of whether it is on load or not, but the greatest advantage this type of coil has is its anti-single-phasing features. It is well-known that if one line of a three-phase supply is disconnected when the motor happens to be running, it will continue running single phase, taking an increased current in the two phases that are left energised and usually burning itself out. The diagram Fig. 3, shews the effect of single-phasing with the Line 2 open on a delta connected motor running single-phase. The line current is indicated by A, and it will be seen that this is 2½ times the normal current. The current in phases Y and Z, shewn by B,

are only about 25% above normal, but the current in phase X, shewn by line C, is nearly 300% of the normal current.

Insurance companies and motor manufacturers tell us that about 80% of their burn-outs are due to this trouble of single-phasing. It is not possible to set the ordinary overload to give protection against this fault, as the overload setting usually has to be high enough to take care of temporary peaks, and as such it will not function with the excess current in two of the phases referred to above, although this current if sustained sufficiently long will invariably damage the machine.

With series trips this weakness is satisfactorily overcome, as the failure of any one line knocks out the switch ; and thus three robust coils provide complete protection, namely, three overloads, three no-current, and prevention of single-phasing.

Most starters have a correct sequence device preventing the switch from going into the running position before the start, but it is also important to have a similar device that prevents creeping into the start position. The mechanism should be arranged so that it is necessary either to close the switch smartly and make proper contact, or be definitely held out.

A small feature that is deserving of special emphasis is the provision of ammeters. These are always to be recommended in the endeavour to educate the user up to the point of agreeing to accept them, even though they cost a few pounds extra. Consider what the ammeter does. It tells the user if the motor is being overloaded, and pays for itself many times over if it saves a burnt-out motor, and the consequent delay and loss of production. An ammeter lets the user know when his load is increasing and, what is sometimes

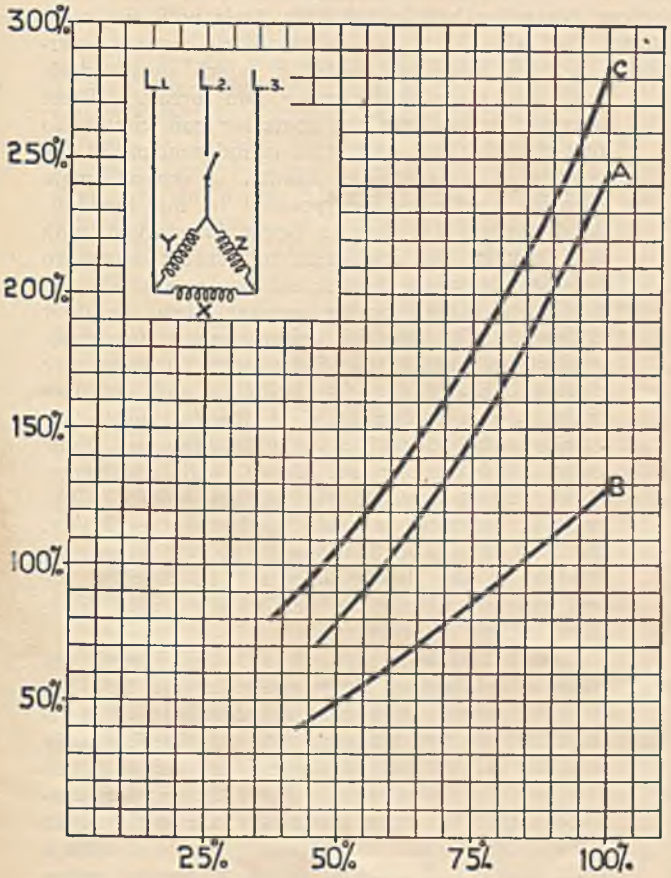


Fig. 3.

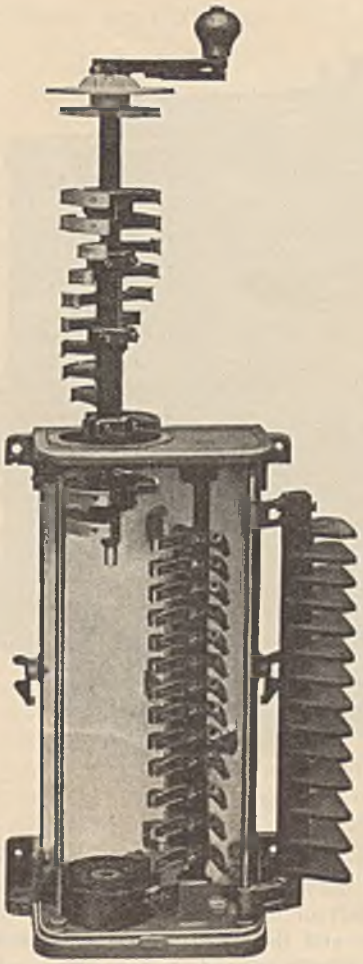


Fig. 4.

more important, when it is decreasing, and whether it would be more economical to put in a smaller motor and among other things, improve his power factor. This knowledge is something of inculculable value, and is apt to pay for itself in all sorts of unexpected ways. When it is so easy to have at all times the knowledge of the current taken, it is well worth the small extra expense of an ammeter.

Pedestal ammeters can be supplied either for mounting on top of the gear itself, or separately for wall fixing, and a special type of terminal box allows of easy access. The right position should be where it can most easily be seen by the operator. For underground work these instruments should be robust and reliable rather than finely accurate. They are not intended for test bed work, although they should comply with British Standards Grade 1 Specification, but what is essential is that they stand up to the bumps and hard work that control gear gets when, say, mounted directly on to a haulage bed.

Drum Controllers.

The remarks herein are general and apply equally to a.c. or d.c. (see Fig. 4). The essentials are that the cover should be firmly fixed and yet easily removable, that the fingers and contacts should be robust with easily renewable tips, and that the arc shields should be of the unit type so that the breakage of one section does not necessitate scrapping the lot. Certain individual makers study the users further than this, and provide a removable cap plate at the top of the

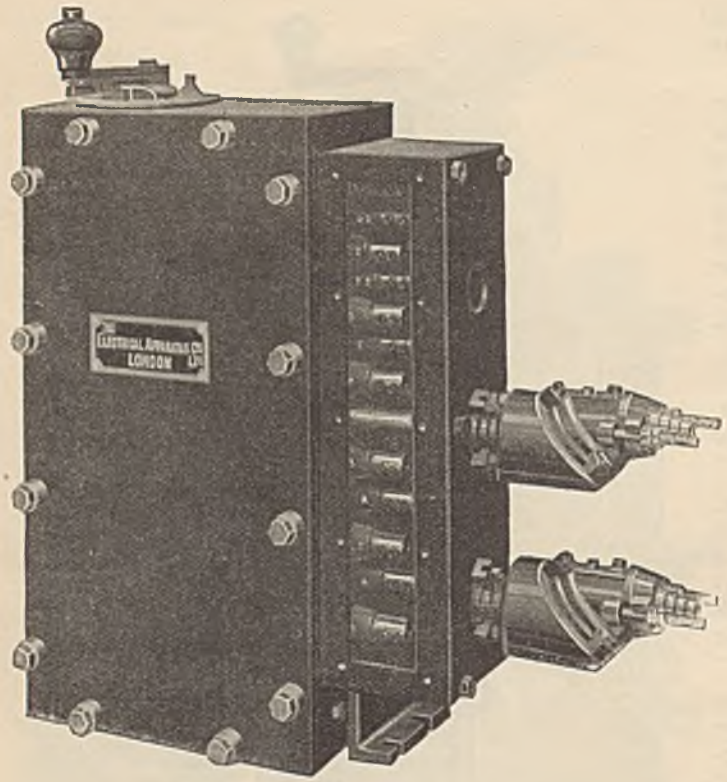


Fig. 5.

controller through which the whole of the drum can be replaced without dismantling. It is essential that the square shaft of the controller be taken right through to the handle and the construction, sometimes employed, of a round spindle pinned is bad ; this makes a very weak spot and one liable to cause trouble in a serious manner, if the holding pin sheers or fails with the controller full on.

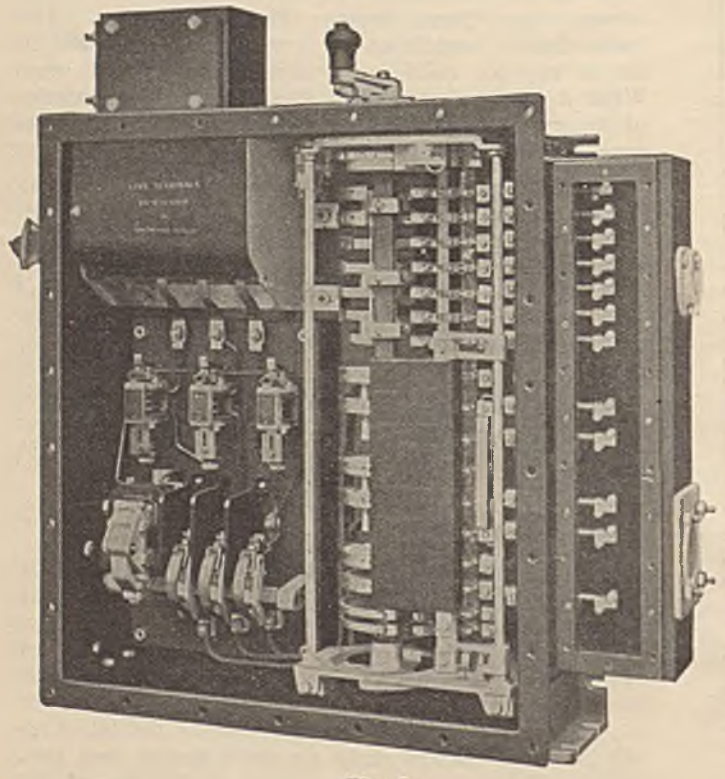


Fig. 6.

The illustration, shews a water-tight controller embodying the features referred to, and indicating clearly the heavier construction necessary for mining work, even though not flame-proof.

Trouble is sometimes experienced due to the spring tension weakening, as the finger is adjusted to take up the wear on the tip, and a new feature is a device whereby the spring has constant tension throughout its whole travel. The back anchoring of the spring is fixed to the actual contact finger, so that as the finger moves forward, so does the complete spring move with it. This means that once the tension is correctly set, it remains constant and avoids two evils, namely, too great tension when the tip is new, and too little tension when the tip is worn away. The illustration, Fig. 5, is of a flame-proof controller clearly shewing the ceiling arrangement in a separate compartment from the main contacts.

The ideal arrangement on controllers is to take the destructive arcing away from the fingers and, as in the case of the heavy duty d.c. starters dealt with earlier, this can be done by a contactor interlocked with the first step, this contactor giving no-volt and overload protection as well as being suitable for inching. The main make and break takes place always on the contactor, and by means of a special relay in the controller head, one contactor can be arranged to serve all three purposes, namely, overload protection, no-volt protection and inching. The contactor can be mounted inside the controller case, or can be mounted outside either near the controller or remote.

Haulage Units.

An extension of this idea is shewn in the next illustration of a complete haulage unit (Fig. 6). Here the one controller handle not only deals with the rotor current, but also by a pair of auxiliary contacts energises a separate three-pole contactor, which always deals with the main stator make and break. Three overload relays trip the contactor coil circuit, so that the overload protection is independent of the position of the controller handle. A separate main isolating switch is incorporated in the top left-hand corner, the handle being interlocked with the door of the equipment to prevent access to the interior when the current is on, and also to prevent switching on the current when the door is open. The separate compartments for cable connections outside the flame-proof enclosure are clearly indicated for the incoming and outgoing cables. This equipment gives the full protection usually obtained with a separate draw-out stator switch, and the one unit shewn, with resistances, is all that is required for haulage control. The same arrangement is made up by another maker, the limit of size in this case being 60 h.p., against 100 h.p. of the first equipment. In function the two units are identical, either being supplied flame-proof or not as required.

High tension equipment or sizes beyond the range of a standard drum controller can be dealt with by means of a master controller, which is mounted on the haulage bed, this dealing only with the coil currents of the main contactors which are mounted separately. Both the master controller and the main contactors are enclosed in a flame-proof case and both are provided with a main interlocked isolating switch to prevent access to the interior when alive.

Resistances.

Various materials are in use for resistances and each has its own particular value. Wire resistances are the most common form and, while the open spiral gives the best cooling effect its tendency to sag and short across adjacent turns is a drawback. Wires wound on asbestos tubes are satisfactory from the heat dissipation view-point and, if proper care is used in their support, make a very good job. Most of the nickel copper alloys are rated to work at a temperature of 300 deg. C. and as the melting point on these wires is in the neighbourhood of 1000 deg. C., it is obvious that there is a big margin. The author has sometimes had a complaint that a resistance is working too hot, and on asking for particulars has been told that the customer cannot keep his hand upon it. An obvious reply to this is: "Why should he want to?" Bearing in mind that the function of a resistance is to dissipate heat quickly and realising the temperatures to which it normally works, it is fairly obvious that this test, while it might serve as a rough and ready guide to the bearing temperature of a motor, is not applicable to a resistance.

Grid resistances are made up in various forms according to the section of resistance material needed for the current being dealt with; they may comprise loops of wire, flat tapes or cast grids. For controller work, a resistance should comply with the three requirements of unbreakable, jointless and rustless. Cast grids, while they are suitable generally for a stationary installation if given ordinary treatment, are not suitable for use underground nor for cranes and other moving or portable equipments, where steel wires or tapes should be used.

As a general rule theoretical considerations are dealt with after a practical design has been evolved, but in the case of the grid unit illustrated in Fig. 7, theory came first and practical design followed. It took about ten minutes to set out the principles on which a satisfactory resistance should be constructed, and about two days to make up a model. However, the best part of two years was taken up in developing the grid unit into its present form.

The points which were set out before considering a practical design are the following:—

(1) Air must be capable of passing freely through the resistance in any plane.

(2) No portion of the active resistance element should in any circumstances be enclosed by or be in contact with insulating material.

(3) Metallic supports should be employed for carrying the element so as to reduce the heating at the point of support.

(4) It must be possible to tap the resistance and to change tappings freely so as to be able to adjust within close limits at any part of the resistance.

(5) The resistance should be unbreakable and held in such a manner as to preclude contact of adjacent parts through vibration or expansion.

(6) Within the limits of a practical size of unit there should be no joints.

(7) The resistance should be capable of being run at red heat in an emergency without being destroyed.

The grid unit illustrated in Fig. 7 complies with all of the above. It has been tested by the Admiralty and approved, who reported that it was far and away the most efficient resistance unit they had ever tested

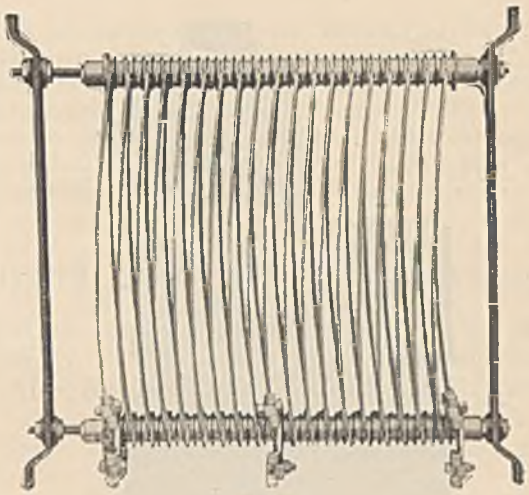


Fig. 7.

as regards wattage dissipated per unit of weight, notwithstanding its robust construction and rigid method of holding the wires.

In the past the Mines Department have been opposed to the use of open resistances, but that was in the days when cast grids were usually employed and, as each section of the grid was a potential source of open-sparking, there was no doubt that the opposition was justified. However, with the coming of the jointless type of resistance the Department have considerably modified their views, and even though the switchgear itself is called for to be flame-proof, there have been installed on a number of occasions resistances of the protected type to work with it, and they have fully met the requirements.

In the Table II. particulars of B.E.S.A. resistance ratings are given, and although these may seem somewhat elementary, it is surprising the number of times

TABLE II.

RESISTANCE RATINGS.

	Starts per hour.	*Time.*	*Proportion of Full Load Torque.*	*Product of Starts, Time, & Torque.*
D.C. Starters.				
Up to 5 h.p.	6	½ min.	1	2
Above 5 h.p.	6	½ min.	1	3
Inching Type	12	1 min.	1	12
A.C. Starters.				
Auto Transformer	4	½ min.	1	2
Slipring	4	½ min.	1	2

	Starts per hour.	*Time on first notch.*	*Time on remaining notches.*	*Cooling Period.*
Controllers.				
Two minute rated	4	½ min.	1½ min.	13 min
Five minute rated	4	2 min.	3 min.	10 min
		Any Notch.		
Continuously rated up to half speed	4	5 min.		10 min
Continuously rated above half speed	Continuous	Continuous		none

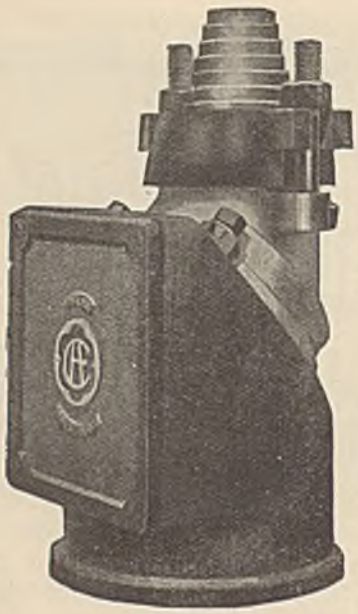


Fig. 8.

the manufacturer has to query resistance particulars as received from experienced engineers. Thus it is specified sometimes that a resistance is wanted for half-hour rating; obviously that is the motor rating, and has nothing whatever to do with the rating of the resistance, which is purely a function of the time that the motor takes to get up speed. Another point is of interest in this Table II. is that B.E.S.A. continuous rating does not mean what it says, and there is a considerable difference in the cost of a resistance of this rating, and one that is truly continuous on every notch. In the author's opinion a new term other than "continuous" should be used for a resistance that cannot be used continuously.

Insulation.

The general tendency is to do away with porcelain and all such breakable and brittle insulators, and to use a solid metal construction comprising a steel shaft with bakelite or moulded mica insulation. The latest practice is not to use any slate at all, due to its tendency to fracture both in manufacture and subsequent use and also due to metallic veins. Ebony Sindanyo makes an excellent substitute and is used in all the illustrations shewn. Its first cost is very much greater than slate, but the time saved in not having to bush the holes makes it, when finished, actually very little more expensive. It is robust, has no tendency to crack, and is impervious to moisture. Its only weakness is that if it is carbonised through an arc it forms on the surface a very good conducting path; it is essential, therefore, that the surface should be kept clean.

Rust Prevention.

Various methods are in force for this, but cadmium plating is generally recognised as being one of the most efficient. Messrs. Cannings, who are experts on metallic plating, said in the *Electrical Review* for May 14th, 1928—"Cadmium Plating is positively the most perfect "known means of rust prevention and protection against "corrosion."

Cable Boxes.

For armoured cables a very satisfactory fixing is by means of universal boxes (Fig. 8), which are provided with clamps for securing the armour and also facilities for sealing. A great difficulty exists underground when handling cables of heavy section, as unless the cable box faces the right direction, both cable and valuable space have to be wasted in "sweeping" it into the box. The type of box illustrated can be turned positively to any angle, and thus directly to meet the cable from whatever direction it enters. An improvement on an ordinary type is a terminal box (Fig. 9), which in addition to the ordinary sealing box has a disconnecting chamber which complies with the latest official requirements ensuring that all fixed connections to the explosion-proof chamber are made at the works, and that all cable connections that have to be made on site are made in a separate compartment.

Earthing.

Mr. Horsley (H.M. Electrical Inspector for Mines) in his report for the year 1929 finds it necessary to emphasise the gross inattention of engineers to requirements of General Regulation 131 G. This reads as follows :—

"Adequate precautions shall be taken by earthing or other suitable means to discharge electrically any conductor or apparatus, or any adjacent apparatus if there is danger therefrom, before it is handled, and to prevent any conductor or apparatus from being accidentally or inadvertently electrically charged when persons are working thereon."

The importance of this regulation cannot be too strongly emphasised when it is read also in the same report that one fatal and six non-fatal accidents were attributable to causes that could not have arisen had the recommended safeguards been applied.

What the above regulation means in practice is that feeders should not only be made dead, but should be earthed and kept earthed while any work is being carried out on them. The Mines Department find that

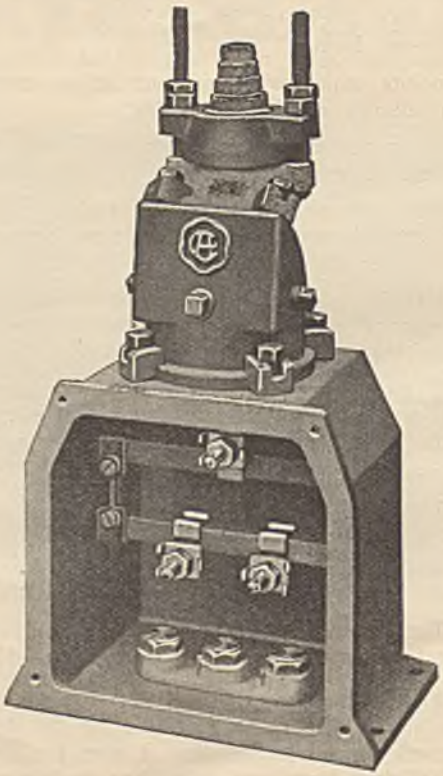


Fig. 9.

it has not been the practice to make adequate arrangements for carrying this into effect. They are therefore pressing very strongly for distribution switches to be so constructed that the outgoing circuits may be earthed, and while the design is somewhat difficult on a draw-out switch, it is comparatively easy on a switch that has a separate mechanically operated isolator. This would have three positions, namely, "on", "off", and "earthed", the arrangement being made that the switch cannot be moved direct from "on" to "earthed" or *vice-versa*, but must first be moved to the "off" position.

A device should be provided for locking the handle in the "earthed" position, and the circuit breaker then be closed, thereby connecting the outgoing cable direct to earth. A device may be necessary to render the overload and novolt releases inoperative while the operating switch is on, in the "earthed" position. This arrangement is of importance in certain instances, for example, in the case of a ring main, as it ensures that the circuit breaker can be closed, and will remain closed even if there should happen to be current flowing due to the other end of the cable not having been made dead. In the case of motor control units, where the outgoing feeder is connected direct to a motor, there cannot be any residual charge left in the cable after switching off, and the Mines Department are not asking for earthing contacts to be provided in such cases. In addition to this provision on new boards, the writer has come across cases where the Mines Department are absolutely insisting upon existing boards being modified to suit this requirement.

(*To be continued.*)

WARWICKSHIRE & SOUTH STAFFS. BRANCH.

The Branch was honoured by the presence of Mr. J. W. Gibson, the President of the Association, at a meeting held in Cannock on January 22nd, last. Mr. Gibson, in a paper entitled "Some Further Notes on Chimney Dust Problems", elaborated upon the subject dealt with in his notable paper read before the London Branch last session and published in *The Mining Electrical Engineer* of January and February, 1930.

This supplementary paper also included descriptions of the apparatus popularly used in the large power stations for the arresting of flue dust which until recently was permitted to pollute the atmosphere.

Numerous micro-photos. of various types of dust from different classes of fuel were illustrated by lantern; it was particularly surprising to observe that in some cases the particles were in the form of hollow spheres which, being extremely light, remained in suspension for some time.

Mr. S. H. Morris moved a vote of thanks which was supported by Mr. J. R. English and expressively carried.

Mr. Abson was also thanked for having kindly acted as lantern operator.

Mr. Gibson, in his reply to the thanks of the members made interesting references to pioneering days and to the crude methods at one time employed to keep a pit going. He mentioned that British trained mining engineers were to be found in all parts and that the Association was doing its part to maintain this world supremacy by encouraging student colliery electricians to obtain their Association Certificates as sure evidence of technical competency.

Further Notes on Chimney Dust Problems.

J. W. GIBSON

(*President of the Association.*)

In his paper read last session before the London Branch the author discussed in a general way the problem of dust collecting, confining the statement more particularly to that part of the subject which deals with the collection of dust from industrial chimneys. In these notes it is proposed to introduce the consideration of the laws governing the separation of solid matter from suspension in a gas. To do this it will, obviously, be first necessary to clear the way by getting some definite idea of the sizes of the particles which are to be dealt with.

The unit of size generally employed is the micron, which is one 1000th part of a millimetre, and which is usually represented by the Greek letter μ

Since the micron is a thousandth part of a millimetre, it is obviously a one 25,400th of an inch. A dimension of this character is much too small for normal useful imagination. One can barely visualise a one 1000th of an inch, but the 25th part of such an amount conveys no definite impression to the mind. It will, however, be not without use to endeavour to get some mental picture of the sizes which require to be considered in discussing the subject. Take some typical instances. (1) A human hair is about 30 microns diameter. (2) One of the main threads from a spider's web is $1\frac{1}{2}$ microns. (3) Machine-made cigarette papers are 36 microns thick; paper for hand-made cigarettes is 18 microns thick. Tobacco smoke particles are about 0.25 microns in diameter.

To obtain sizes of this order by ordinary direct methods of measurement is of course not possible, and the author has had to get them by means of the microscope. Possibly a more striking and easily visualised example would be by reference to a golf ball. A golf ball is approximately 1.69 inch in diameter and weighs about 1.69 ounces. By comparison with a grain of dust 10 microns diameter, if the dust particles were made of the same material as the golf ball it would weigh 4300^3 as much. In other words, if the dust particles were as large as the standard golf ball, the imaginary new golf ball to similar proportions would have become 202 yards diameter, and would weigh 3,749,160 tons.

At first sight it might be considered that a particle of 10 microns is too small to be of any practical importance, but a sufficient number of particles of this size may, and often do, constitute a nuisance, and those interested in dust removal have more and more to face the problem of how these extremely fine particles can be effectively dealt with.

Dust elimination is a comparatively new problem, so that there is very little information available as to the actual laws which must be obeyed if any dust collecting plant is to be a success.

Since the date of the last paper by the author various developments in what may be justly considered a science, have been made, but nothing has occurred to cause the author to change his opinion that, to deal with the bulk of the problem, collectors working on the centrifugal principle must be employed.

The laws which have been deduced practically all refer to the rate at which a dust of known specified gravity and known size will fall out of suspension from gas, also of known specific gravity, the gas being considered as in a quiescent condition.

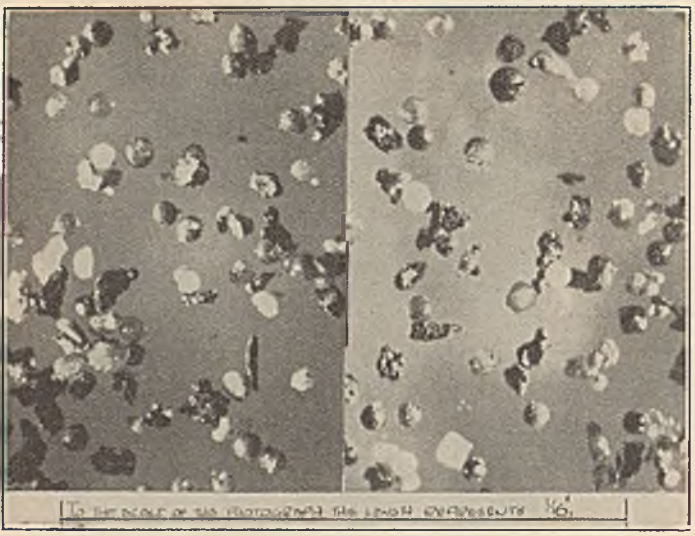


Fig. 1.—Microphotograph of dust used in Stoker Dust Tests. Right—between sizes 0.060 mm. to 0.075 mm. diameter. Left—between sizes 0.075 mm. and .100 mm. diameter. In the dust used the former amounted to 9%, and the latter to 13% of the dust by weight. This print shews clearly the hollow glass-like spheres and white opaque particles, both of which will generally float on water.

It is quite possible that such laws will not apply in their entirety to the conditions which will prevail in the practical and industrial work of dust collection, but the author believes they will hold sufficiently closely to enable one to obtain a great deal of useful information as to the limits within which dust collection may be undertaken with confidence of its success.

Solid matter in a gas behaves in three different ways, dependent largely upon the size of the particles, and to a lesser degree upon their density. Impalpably fine solid matter will be in Brownian movement. Here the size of the particle is comparable with the distance apart of the molecules of the gas. In consequence the particles will not be equally bombarded on all sides by the motion of the molecules of the gas, but will be buffetted about, and its rate of fall, even in a quiescent gas, will be infinitesimally small.

Solid matter of larger size, though still quite small, will obey Stokes Law. Particles of this class will quickly attain a uniform velocity of fall in still air, and the velocity so attained will be of comparably small dimensions. Particles of this class of similar material and srtucture will attain a velocity which will vary with the square of their diameter. Larger particles will fall more freely in still air and the velocity which they can attain in falling will be proportional to their respective diameters. Still larger particles will obey the ordinary gravitation law, but particles of this size are outside the scope of dust collection.

Considerable research appears to have been made on the terminal velocity which a particle can attain when falling in still air under the action of gravity. Unfortunately, little scientific research seems to have been made on the motion of a dust particle relative to its enveloping gas when the gas itself is in motion, and when other gravitational forces are employed.

Using the laws which govern the rate of falling of a particle in still air, Professor Gibbs of University College, London, in a paper read before the Institute of Fuel, stated that the terminal velocity of particles of dust of varying sizes under the action of the accelerating force of gravity would be as follows :

Diam. of Particle Microns	*Velocity of Fall. Cms/Sec.*	*Ft. per Sec.*
1,000	748	24.9
450	351.6	10.5
300	197.3	6.58
150	78.9	2.63
130	73.8	2.4
66	18.4	0.6
13	0.738	0.29 inches/sec.
1	0.017	0.007
0.1	0.00017	0.00007

From this table it would appear that for small particles of the order of 60 microns and less the rate of travel relative to the gas is so small that one of two

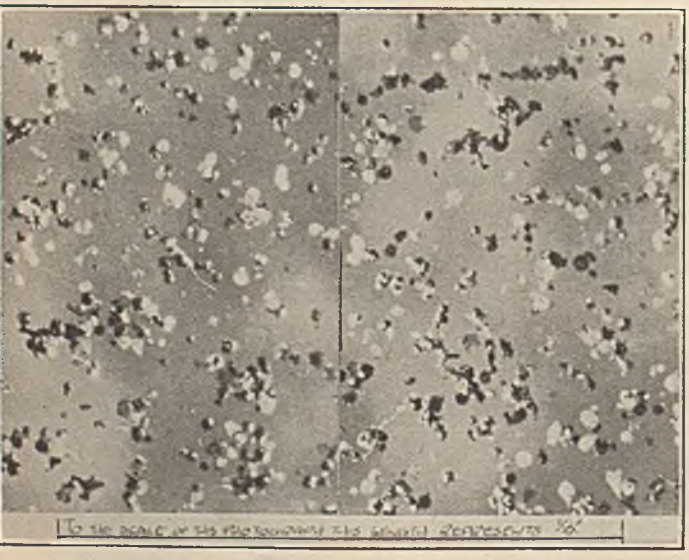


Fig. 2.—Microphotograph of dust less than 0.060 mm. diameter used for Stoker Fired Dust Tests. It amounted to 25% of the dust by weight. By actual measurement of the particles it will be found that a large percentage is very much smaller than the 0.060 mm. diameter.

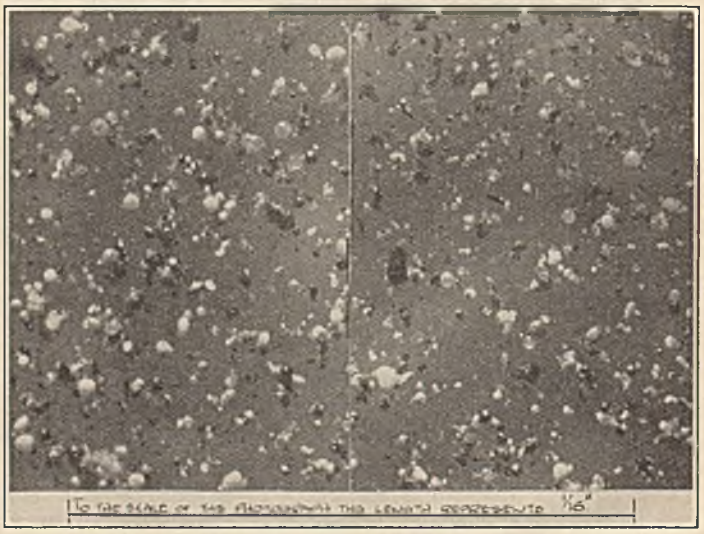


Fig. 3.—Microphotograph of dust less than 0.060 mm. diameter used for Pulverised Fuel Dust Tests. It amounts to 43% of the dust by weight. Note the extreme fineness of some of the particles and the preponderance of the glass-like and opaque particles as compared with the Stoker Fired Photographs.

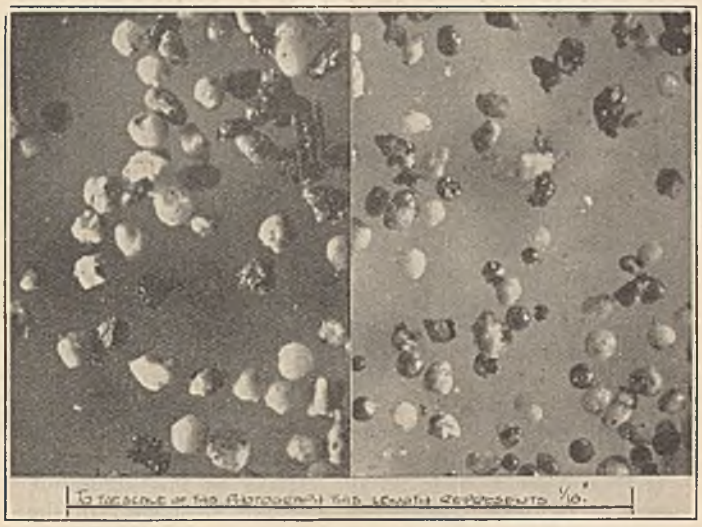


Fig. 4.—Microphotograph of dust used in Pulverised Fuel Dust Tests. Right—between sizes of 0.060 *mm. to* 0.075 *mm. diameter. Left—between sizes* 0.075 *mm. to* 0.100 *mm. In the dust used the former amounted to* 9%, *and the latter to* 18% *of the dust by weight. This photograph gives a good idea of the spongy carbon particles caused by the cooling of the particle of fuel during distillation.*

conditions must be fulfilled if they are to be collected with certainty.

(1) The maximum distance which the dust particle is required to travel in order to be entrapped must be comparatively small.

(2) The time during which the particle is under the influence of the accelerating force must be considerable.

The first condition pre-supposes a collector of comparatively small size; and the second, that the gas within the collector *must* make more than one turn within the collector before it finally leaves the collector.

In passing, it may be noted that the latest type of dust collectors now being erected at the new Ironbridge Station of the West Midlands Electricity Authority comply with both these conditions. The collectors are installed in multiple and connected in parallel, thus keeping the size of each collector as small as possible, consequently, the distance which even the most unfavourably placed particle of dust has to travel is kept at a minimum, whilst the gases which convey the dust in suspension may take many turns within the collector itself, thus giving the dust particles the longest possible time in which to effect the necessary travel relative to the gas velocity.

In the course of research into this problem of separating dust from the conveying gases, many interesting facts have come to light, in connection with some of which we are still in search of a physical explanation. Quite early in our investigations we found that some dusts were easier to separate, i.e., collect, than others, and this irrespective of their fineness or weight. Thus, cork dust which is very light and fine, is easy to collect, and high efficiencies of collection are easy to obtain, whilst Flatters compound—a grinding material used in the manufacture of pottery—although heavy and no finer than cork dust, is a difficult material to handle. Many metal dusts present similar difficulties. Electrostatic action has been suggested as an explanation.

In addition to the size of particle the effects of the temperature and viscosity of the gas have also been studied, but as the results are speculative rather than concrete, the author proposes to content himself with observing that a comprehensive series of tests at a works' laboratory with dust from industrial plants, demonstrated that as far as flue dust is concerned, the collecting efficiency within a temperature range of 60 degs. Fah. up to 600 degs. Fah. is only influenced to a minor degree.

NORTH OF ENGLAND BRANCH.

Routine Examination and Testing by the Colliery Electrician with special reference to the testing of the Earthing System.

J. A. B. HORSLEY,
H.M. Electrical Inspector of Mines.

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

Mainly at the instigation of Mr. H. J. Fisher, a member of this Branch, the explanatory notes upon Regulation 131 (c), in Mines and Quarries Form No. 11 as revised in January, 1930, were expanded to suggest definite periods for the examination and test of various parts of a colliery installation by the responsible electrician, by way of defining the requirement in this Regulation, that this shall be done "as often as may be necessary to prevent danger".

It may be useful therefore to quote those notes verbatim, as they are printed on pages 61 and 62 of the Official Publication, as follows:—

EXAMINATIONS.

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

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

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

INSULATION TESTS.

(d) *A Daily Test*, if possible, of the system as a whole.

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

(f) *A Quarterly Test* (1) of the cable system in sections, and (2) of all motors and switchgear individually.

EARTH CONDUCTOR TESTS.

(g) *A Weekly Test* of cables and apparatus subjected to especially rough usage, as at the coal face.

(h) *A Quarterly Test* of all other parts of the system in sections.

In making these suggestions the principle has been followed that the more dangerous parts of the installation and those that, from the nature of the use to which they are put, are more likely to become deranged, shall be examined and tested most often, i.e., at the shortest intervals of time.

On this principle, daily examination is suggested for flame-proof enclosure, for plug and socket earthing contacts and of trailing cables ; and, as a general precaution daily tests of the state of the insulation of the system as a whole.

As to flame-proof enclosures, the explosions due to electricity that occur from time to time almost invariably indicate (i) that the faulty condition could easily have been discovered by intelligent examination and, (ii) that it was not of recent origin. Similarly, accidents attributable in part to ineffective earthing at plug and socket junctions make it abundantly clear that the earthing contact has not been critically examined and that the defects were not developed immediately before the accident.

Trailing cables, with their concomitant, the plug, were responsible for 109 fatal and non-fatal accidents in the five years 1925-1929 inclusive, or nearly 37 per cent. of all electrical accidents in that period. While the accident often coincides with the development of the defect, it will not be denied by anyone, who spends much time underground in districts in which coal face machinery is used extensively, that the accidents are few in comparison with the opportunities that exist. It is far too common to receive reports of trailing cables found in a condition of disrepair such as to involve considerable danger either of electric shock or of "open sparking".

As to a daily observation, by test, of the general state of the insulation of the system, this is perhaps the most difficult in application excepting where the system is a simple one fed directly from busbars at bank. For such simple systems there is much that might be said in favour of a continuous record of the state of the insulation, such as may be obtained from a chart or graphic recording leakage indicator. A word of warning is necessary whether the indicator is of the chart type or the more common simple indicating type. It is this : unless the insulation of the system under observation is maintained at a high standard the readings of the indicator may be, and in fact will soon be, masked by distributed leakage upon the "network".

For example, in a three-phase, so called insulated system a number of small leakages upon the three phases will completely invalidate the readings obtained from the busbar indicator. Again, if the indicator is connected between "earth" and the neutral point of an earthed three-phase system, leakage upon one phase for which there is a return path through leakages upon the other phases will not be shewn by the busbar indicator. The validity of the readings of the leakage indicator should, therefore, be checked periodically, either by disconnecting the network and testing the insulation with a "Megger", or by applying an artificial fault to each phase in turn and observing whether the indicator responds.

As to periodic examination of switchgear, especially with reference to oil-immersed switchgear and the setting and operative condition of over-current trip devices, it is not at all unusual to find that the oil level is below that intended by the designer and that the "loading of the safety valve", viz. : the trip coil, is not known. Examples may be found in the Annual Reports of the Author.

It is suggested, under item (c), preceding, that a quarterly examination should be made, *inter alia*, of the rotor air gap in motors, as a check upon the wear and alignment of bearings. This may be considered by some as a redundant piece of advice, but reference to the breakdown of a 75 h.p. 3300 volt haulage motor, recorded at the bottom of page 21 of the Author's Annual Report for 1929, will shew that the advice is not unnecessary and that expensive repairs may be entailed by neglecting this simple and elementary precaution.

TESTING OF EARTH CONDUCTORS.

Let us pass now to a consideration of the testing of the earthing conductors which form such an important part of a mine installation. A weekly test is advised of cables and apparatus subjected to especially rough usage as at the coal face. This envisages trailing cables, pliable armoured cables and plug and socket couplings. These components, being at the extremities of the system can be laid off for testing without interrupting the work of the mine, by choosing a convenient time, and do not entail either overtime or Sunday work. Nevertheless, it is a fact that in too many instances these tests are never made at all. Harsh as this accusation may seem there is abundant evidence in support of the statement, in the records of accidents and in the reports of inspections, that are not published.

Where the earthing circuit for portable and semi-portable machinery is neglected there the stage is set for an accident and there is no excuse for such neglect, unless the men and the means are withheld, for the test can be made with dispatch and with sufficient accuracy, with easily portable instruments that have been designed for that purpose.

Many of the members of this Association will be familiar with the instruments just referred to ; the simplest form consists of a secondary cell, an ammeter scaled to read direct in ohms, or fraction of an ohm, and two contact making spikes attached to flexible conductors ; the whole contained in a box and weighing only a few pounds.

Such an instrument may be relied upon to give sufficient warning of faulty earthing conditions—provided it is kept in proper repair, which includes regular recharging of the battery. That remark may appear to be platitudinous but it is based upon actual experience that it is a necessary reminder. It is wise to check the accuracy of the testing instrument from time to time and the following equipment is suggested for that purpose.

A hard wood board mounting terminal blocks with spirals of resistance wire attached to the blocks by silver solder—if the resistance of each element is known any desired resistance, within the scope of the equipment, may be selected for proving the testing instrument.

Assuming that the range of resistance desired is from 0.03 ohm to 3.0 ohms this can be provided for by means of six elements, viz. : three of 0.1 ohm each and three of 1.0 ohm each, arranged as shewn in Fig. 1. By various combinations of the elements in series and parallel with this simple appliance a wide choice of resistance is available between 0.03 ohm and 3.3 ohms. With the addition of a suitable low reading voltmeter such a board will serve as a rough potentiometer for measuring current over a considerable range, or for the comparison and evaluation of low resistances, and it will prove useful for many other purposes than that for which it is primarily intended.

Let us now consider the testing of the earthing conductors comprised in the system as a whole ; but, before discussing methods it will be worth while to pause for a few minutes to consider what is the object in providing earthing conductors. Some may say the object is "in order to comply with requirements of General Regulation

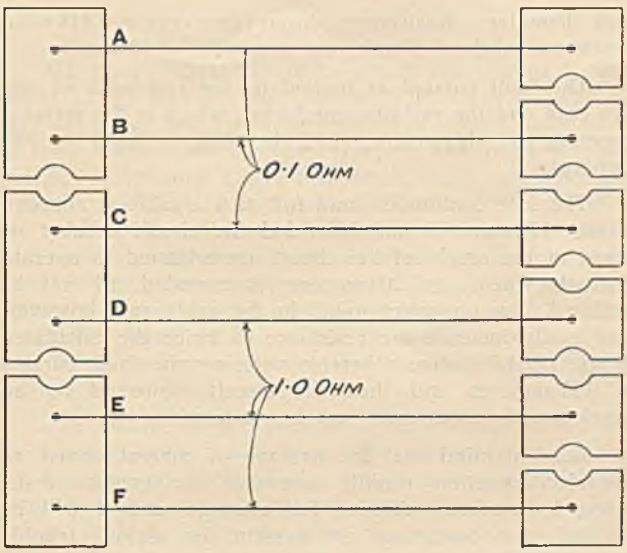


Fig. 1.—Selective resistance for checking accuracy of Earth Conductor Testing Instrument.
Elements A *to* F *in parallel* 0.03 *ohm.*
Elements A *to* F *in series* 3.30 *ohms.*
Intermediate values by varying the number of resistance elements in series and parallel.

125 (a)" : and, in not a few installations, the matter would appear to have gone to rest there, the colliery engineer's intelligence having been lulled to a false sense of security, perhaps, by the definition of the term "earthed" which appears in General Regulation 118. It is worth while to quote that definition here—it reads —thus : "Earthed means connected to the general mass of earth in such manner as will ensure at all times an immediate discharge of electrical energy without danger."

Now, a condenser isolated from the source of electrical energy from which its charge was derived, may be discharged by connecting the charged plate to earth : but what if the charge is continuously renewed ? It is a commonplace of electro-technics that a conductor through which a current is flowing will exhibit difference of potential between its parts and that phenomenon will be exhibited in an earthing conductor while it is carrying the current due to a fault, i.e., a failure of insulation between one pole or phase of the system and the framework of a motor or other electrical appliance which is earthed by means of the earthing conductor.

In other words there can only be no difference of potential between the extremities of the earthing conductor so long as no current is flowing in that conductor. From which it follows that the earthing conductor can only hold the earthed apparatus at earth potential if there is no current flowing in that conductor. This condition is only satisfied : (i) if there is no fault in the system or, (ii) if there is no return path for the fault current.

As earthing conductors are provided to protect persons from electric shock upon the occurrence of a fault the first named condition may be dismissed from further consideration and attention may be confined to the second condition.

The second condition, viz. : that there shall be no return path for the fault current, is but rarely satisfied in practice, for it involves perfect insulation throughout the system, except at the place and at the time of the fault. Nothing therefore can be built upon that hypothesis although there are still some who affect the belief that a so called insulated system is safer than one in which one point is deliberately earthed in the manner permitted by General Regulation 124 (c).

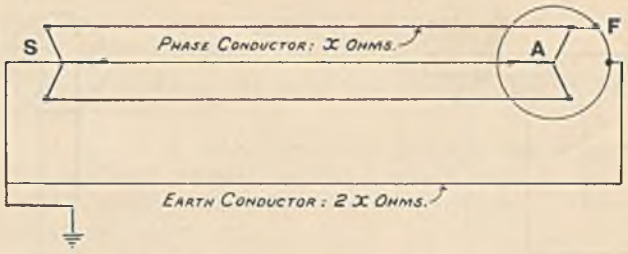


Fig. 2.—To illustrate Rise of Potential on Earthed Apparatus under fault conditions, due to drop of potential over earthing conductor.
S : *source of current, phase to neutral* 360 *v.*
Volts drop over earth conductor $\frac{2}{3}$ *of* 360 *v.*
Volts drop over phase conductor $\frac{1}{3}$ *of* 360 *v.*
Potential difference between A *(frame of earthed apparatus) and adjacent earth* = 240 *v.*

Apart from the probability, to put it no higher, of a considerable amount of distributed leakage upon the system, there is often a return path for fault current through the leakage indicator ; while, in a three-phase insulated system the effect of the electro-static capacity of the cables and motor and transformer windings is to hold the neutral point approximately at earth potential and to provide a return path, for fault currents, of sufficient capacitance to result in a serious or even a fatal shock upon making contact with one live terminal, at any rate in a high pressure system.

The Protective Value of Earthed Systems.

Let us see then how far the earthing of apparatus is a safeguard against dangerous electric shock. A hypothetical illustration will serve to direct attention to the difference of potential that is bound to exist under fault conditions, between the earthed apparatus and the adjacent earth itself.

The assumptions for the purpose of this illustration are shewn diagrammatically in Fig. 2. A three-phase system with the neutral point earthed direct ; a phase to neutral pressure of 360 volts ; an earthing conductor having a resistance twice that of one live working conductor, between the earthed apparatus and the earthed neutral point of the system.

If there is no resistance at the fault itself it will be obvious that the pressure will be expended as to one-third in driving the fault current through the working conductor and as to two-thirds in the earthing conductor. That is to say the potential of the earthed apparatus will be 240 volts above that of the earthed neutral point of the system.

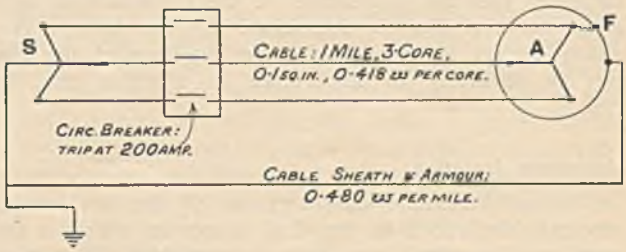


Fig. 3.—To shew Influence of Resistance of circuit upon automatic isolation when fault occurs.
S : *source of current, phase to neutral* 360 *v.*
A : *earthed apparatus, fault at* F.
Resistance included in fault circuit. 0.898 *ohm.*
Fault current = 360 ÷ 0.898 = 397 *amps.*
If fault circuit resistance is 1.796 *ohm. then fault current is* 198 *amps. and circuit breaker may not trip.*

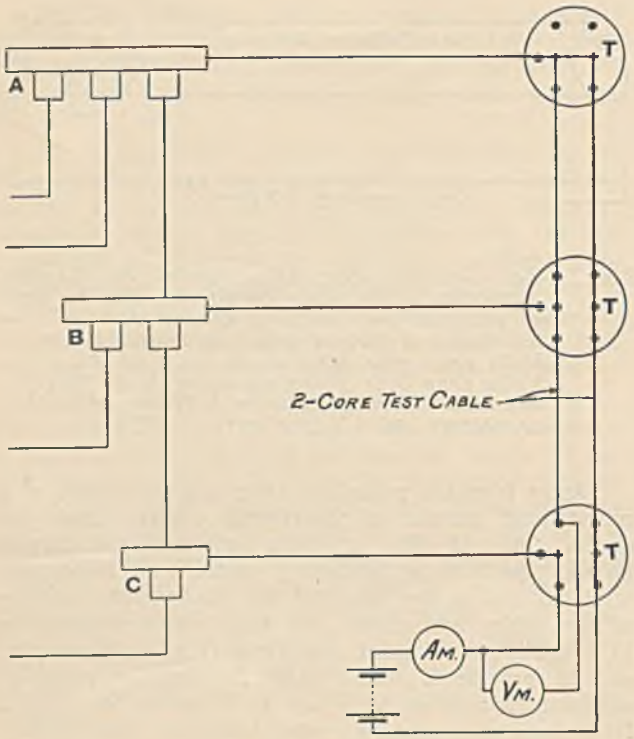


Fig. 4.—Diagram of Permanent Testing Circuit for earthing conductors comprised in system.
T: *test cable terminal boxes, links inserted for through test from* C *to* A.

Now, 240 volts alternating pressure is certainly a lethal voltage and anyone touching the earthed apparatus under these conditions will be in jeopardy. Earthing alone, therefore, even where it satisfies the requirement of General Regulation 125 (b) will not, *per se*, suffice to prevent danger. Earthing then is only a necessary preliminary to the immediate and automatic isolation of the circuit in which a fault has occurred.

If a permitted point of the system is not earthed, e.g., the neutral point of a three-phase system, there can be no assurance that the faulty circuit will be cut off either automatically or immediately. That the circuit should be isolated automatically is not likely to be disputed but the additional requirement that this shall follow immediately may be challenged by the hypercritically minded. However, until the medical profession adduces evidence that the duration of the electric shock is relatively unimportant the Author feels warranted in assuming that the seriousness of the consequences is in some material degree determined by the time during which contact is maintained. The duration of the contact is obviously of importance as affecting the fire risk.

Automatic Isolation.

It will facilitate consideration of the problem of automatic isolation, in the dual aspect in which it has just been presented, to take a particular illustration, such as that shewn diagrammatically in Fig. 3. The data here is, as before, a three-phase system with the neutral point earthed and 360 volts as the phase to neutral pressure; but, instead of the hypothetical case, a particular example is used, viz.: A mile of three-core 0.1 square inch paper insulated lead sheathed cable with two layers of armour comprised of steel wires each 0.08 inch diameter. Resistance of one live core: 0.418 ohm. Resistance of lead sheath and armour = 0.48 ohm.

The fault current as limited by the resistance of one live core and the earthing conductor, which is the metallic covering of this cable, will be 360 ÷ 0.898 = 397 amperes.

The safe continuous load for such a cable is approximately 170 amperes and provided the circuit breaker or fuses, at the origin of the circuit are adjusted to operate instantly when, say, 200 amperes is exceeded, all may be well. A few imperfect joints in the cable run, however, may easily increase the resistance to twice the calculated figure, or 1.796 ohms, thereby reducing the fault current to 198 amperes and then the circuit protected by an over-current cutout may not be isolated.

Bear in mind that the passage of current across an imperfect junction rapidly increases the contact resistance, by surface oxidation for example, and it will be realised that conditions are present for serious trouble on the line, whether from shock or from fire.

With leakage protection, however, by reason of the much better protection against a sustained fault obtained thereby, the chances of untoward happenings are greatly reduced. Nevertheless the importance of keeping the resistance of the earthing circuit at the lowest possible value must be insisted upon.

It is impossible to judge of the resistance of a joint, or even to tell whether it is a reasonably good joint, by inspection alone. Tests are necessary. The usual test as applied from end to end of a circuit involves cessation of supply through that cable and no little preparation, disconnection of apparatus, travelling to and fro and so forth, all of which costs money and takes time. It is inevitable that these tests are not made with that regularity or frequency that is, to say the least of it, desirable.

The Author therefore invites consideration of the following suggestion whereby any circuit may be tested, at any time, without interrupting for a moment the use of the cable or apparatus associated therewith. Fig. 4 shews this proposal diagrammatically. It will be seen that it requires the provision of a permanent test or pilot cable between the extremities of the circuit to which the tests are to be applied.

The diagram is sufficiently explanatory but it may be pointed out that the same test cable could be used conveniently as a telephone circuit either for the general purposes of the mine, or for emergency use by the simple addition of plugging contacts in each terminal box and a self-contained portable, or fixed, telephone. The saving of time over a single emergency repair, not to mention the general convenience to the electrical staff of such means of communication, should suffice, in the Author's submission to secure for this suggestion the serious attention of all colliery engineers.

The sense of security derived from regular testing of the earthing conductors cannot be evaluated in terms of money but this consideration also should make an appeal to the management.

To sum up: examination and testing does not receive that attention which it deserves as the only means whereby incipient defects may be discovered before they result in accident or serious interruption of the regular use of the plant; and this neglect is due in part to failure to understand its real object, but in part also to the inadequacy or inconvenience of the equipment that is generally available.

Discussion.

Mr. H. J. FISHER said he considered routine testing especially of portable or semi-portable apparatus, to be very necessary and so important that it should be effected at least once a week. Mr. Horsley had touched upon trailing cables and a question arose there in connection with the earth wires in these trailing cables. Very often the earth wires got broken and Mr. Fisher knew of at least one fatal accident which occurred through the earth wire having been soldered and the joint breaking. Only the other day in looking through a cable-maker's instruction pamphlet he noticed instructions for sweating with a sleeve and solder joint—a method which he considered to be dangerous.

The testing of air gaps is a very simple thing, but there were many cases where the mere testing of the air gap was no good at all: for instance, with a large haulage motor at rest the air gap may seem perfect, but in such haulages the gear driven pinion is apt to get on top of a sprag wheel.

With regard to the method of testing or calibrating the testing sets, mentioned by Mr. Horsley, Mr. Fisher used similar arrangements and also in taking the megger tests.

Mr. Fisher said he would like Mr. Horsley's opinion whether supplementary earths in suitable places in the mine, in sumps of the pumping plants, etc., or in other wet places in the pit, would not be a very great help.

Leakage trips were very necessary, especially in the case of all portable apparatus; they should be set at not less than 5% of the full load current. Some time ago he had a case of a small ten horse power motor where part of the winding went to earth and a constant current of eight amperes was passing through, although leakage protection was provided for twelve amperes and the men did get slight shocks.

Mr. H. W. CLOTHIER.—In the second illustration the author has shewn how, on a 360 volt circuit with a fault to the frame, there may be a potential difference of 240 volts between the frame and the real earth, due to the comparatively high resistance of the cable sheaths to earth and to the fact that the apparatus may not be making a direct earth. In other words, we have to look upon a mine as if it were an insulating tube, or at least an imperfect conductor buried in the real earth. So a man standing on the ground, if dry, would not get a serious shock, but if he happened to be standing on a rail which at some part of its length made a good earth contact then, on touching the faulty framework, he would get the full 240 volts across his body. It might so happen that in taking one step across the ground he would be bridging ground at a marked potential difference.

Corresponding conditions were met with in the power station and in the substations, in factories and also in the home. With the exception of the latter it was the universal practice to earth the framework of the apparatus direct, and to bond together all metalwork in the neighbourhood of the electrical conductors. In power stations all framework was bonded and joined to earth plates. The same was done at the substations, and in factories portable appliances were connected by earth wires which, in turn, were joined up to the building stanchions. So there were many junctures to earth. But in mines it would appear that the cable sheath and earth conductors in trailers had to do it all, that there was only one intentional junction to earth and that earth connection a long way back and at the surface. Hence the somewhat puzzling conditions which may exist as were shewn on the author's sketch.

There would appear to be two ways of reducing the 240 volts :—

1. To insert more resistance between the neutral point and earth at bank, provided that it could be done without undue interference with the operation of the leakage protection.

2. To earth in more places than at the bank, thus putting the real earth in parallel with the cable sheaths. Were it possible to bond all metal-work including rails, and at all convenient places join the bonding to earth plates or water pipes, would it not considerably reduce the risk of dangerously high potentials across metal and wet ground which could be bridged by the body?

This local earthing, incorporated with the neutral resistance at bank, had doubtless been fully considered. Were the difficulties of maintaining the bonding too great to guard against the risk of open-sparking between adjacent metal-work insecurely earthed? In any case local multiple earthing at pumps and other suitable places might at least introduce the benefit of lowering the total resistance to earth which was otherwise dependent entirely on the cable sheaths.

Mr. Clothier supported the author's plan for a separate pilot circuit for checking the conductivity of the earth circuit, and enquired as to the type of cable proposed, and whether there was any additional risk introduced by the possibility of this pilot being accidently alive on the occurrence of a fault to earth.

He also asked for information on the proportion of British Standard plugs used, and for confirmation of the quality of the earthing contact on that device; also, had it proved itself to be a safety factor considering the large proportion of mining accidents which occurred at the coal face?

Mr. Horsley had mentioned the accident caused by a man putting his finger into a contact tube at the far end of a live trailing cable, and Mr. Clothier could but agree that it was no fault of the Standard Specification. The safeguard against such accidents was the electrical interlock by which the gate-end switch was automatically opened when the plug was withdrawn from the coal-cutter. The Specification makes provision for this safeguard.

Mr. J. H. C. BROOKING.—A point that seemed to be receiving less attention than it deserves is the fact that about 37% of electrical fatalities were due to trailing cables and fittings, a number of these being caused by the used of trailing cables without any ferflex protection. The ferflex covers soon lost conductivity owing to the braided wires being corroded by the free sulphur in the rubber, the tinning having been chafed off by the repeated bending of the cable. There was so much trouble in repairing the ferflex to give efficient conductivity that such cables were generally used without any earthed braiding at all. He thought Mr. Horsley would agree as to the risk of fatalities through this, and that he would like to have earthed braid in connection with all trailing cables used. Unfortunately, there were not many collieries with suitable apparatus, and methods, for properly jointing the ferflex and for vulcanising the repaired cab tyre sheathing.

The last time Mr. Brooking had had the pleasure of speaking at the Branch, he mentioned that experiments were being made by the same colliery company who first used cab tyre sheathing with regard to another

type of trailing cable having insulation and sheathing (called Pernax) which contained no sulphur to corrode the copper wires. He believed those trials were nearing success. They were therefore likely to be followed by an important jump forward in the manufacture of trailing cables in which an earthed braiding could be used, in which there would be less need to make repairs and with which less apparatus and trouble in making repairs to the cable sheath would be needed than for cab tyre cables.

Mr. HILL said he had been especially interested in Mr. Horsley's references to ferflex trailing cables. It was undoubtedly a comforting thought to know that all the live conductors in a trailing cable were surrounded by a metallic sheath or envelope at earth potential; but, unfortunately, that did not always work out in practice. Mr. Hill had had a considerable experience of ferflex on d.c. concentric systems and had regretfully come to the conclusion that it was far from perfect. He had seen cables with the ferflex completely disintegrated, no doubt due to the presence of sulphur in the rubber, and at one time it was no uncommon thing to discover the ferflex broken at each end, in the vicinity of the pommells, and yet be intact in the remainder of the cable. Under such circumstances, ferflex immediately becomes a source of potential danger. They were withdrawn from use. It was interesting to hear Mr. Brooking hint that the manufacturing difficulties of this type of cable were nearing solution, and Mr. Hill would be happy to again consider the use of ferflex type cables if the manufacturers would guarantee reliable service.

Mr. TAYLOR enquired whether Mr. Horsley had experience or knowledge of the failure of earth leakage protection due to the transformers or relay coils being faulty? It would appear that the reason for the non-operation of the leakage protection in a case quoted by Mr. Hepburn was due to the plunger sticking and as he had mentioned 12% tripping, I assume that the Earth Leakage Protection was relay operated. The relay could be tested to shew whether the tripping circuit was faulty or not and the bringing of switches to bank and testing them for leakage operation did not appear to be necessary. The only additional test one could get was a test on the transformers and relay coils; Mr. Taylor had never known one instance of the transformers or relay coils being faulty. The transformers as a rule were run in with compound and there was absolutely nothing to go wrong on this portion of the equipment, and therefore, the expense of this additional test, in his opinion, was not justified. The tripping circuit was the place where danger of non-operation would exist, and that circuit could be tested by operating the relay with the hand testing device.

Mr. HORSLEY (in reply).—Referring to the case quoted by Mr. Clothier, the contact between the motor frame work and the adjoining earth may be a high resistance contact whereas the earth itself is quite a good conductor and the man may be making good contact with the earth. Certainly if the machine is making contact with the earth, that connection will shunt some of the fault current and will therefore reduce the difference of potential between the machine and earth.

Both Mr. Fisher and Mr. Clothier raised questions as to the advisability or advantage of supplementary earth plates in the mine. Undoubtedly such additional earth plates should make for safety inasmuch as they should reduce the potential drop over the earthing conductor, but they introduce the risk that they may be disconnected unknown to the electrician. When the present regulations were introduced they swept away permission to rely upon local earth plates and required one earth plate at bank probably for the reason that local plates had proved to be unreliable. If it can be relied upon it is advantageous to have a local earth plate but if the local earth consists merely of a piece of pipe driven into the ground and left to look after itself, it is more likely to lead to danger than to contribute to safety.

Mr. Horsley said he was not sure whether he had succeeded in making his point clear in the diagram, Fig. 2. The assumption there is that the coalcutting machine is making very imperfect contact with the general body of earth and for all practical purposes is insulated. The man, however, generally seems to make a good connection with earth and consequently diverts the major part of the leakage current. He is in effect a shunt to the earth conductor. The difference of potential shewn in the figure will be exhibited under the conditions postulated. It can only be reduced by reducing the resistance of the connection between the machine and the main earth plate. A local earth plate, where practicable, can be used to reduce that resistance by using the general body of earth as a conductor in parallel with the earthing conductor shewn in the Figure.

Mr. Fisher referred to the question of repairing trailing cables. That is a very important question and in the case of the more complex types of trailers the repair is a difficult mechanical operation requiring considerable practice. With the necessary practice and skill a very good repair can be effected but it should never be considered to be complete until the joint has been vulcanised.

Perhaps the most difficult repair is that of a ferflex screened cable but even this difficulty can be overcome by the exercise of some ingenuity.

Referring to the pilot testing cable shewn in Fig. 4, Mr. Clothier had suggested this might introduce a subtle danger in the event of a fault involving the pilot cable. Mr. Horsley admitted that one must take the risk of the occurrence of a fault upon the circuit under test while the test is in progress but with suitable precautions this risk could be reduced to very small dimensions. The testing cable should be able to take care of itself, if suitably constructed and provision is made, in the terminal boxes, for disconnecting it from the armouring of the power circuit cables when a test is not in progress.

Mr. Clothier had asked for some statement as to what proportion of British Standard Plugs were now in use. Mr. Horsley could not answer: he did not know; he saw a considerable number and heard of many. He was glad to say that comparatively few accidents occurred with the British Standard plug but there had been a few instances of breakdown of the insulation. He understood that the cause had been traced and that an appropriate remedy had been found. A fatal accident occurred recently involving a plug of that type and the circumstances may be worth mentioning on this occasion.

A pliable armoured cable terminating in a British Standard Plug was used to make the connection between a switch mounted on a gate-end loader and the coal face conveyor. The plug was interlocked with a switch mounted on the conveyor so that it was impossible to insert the plug unless the switch was off. The conveyor had been re-erected and the deputy in charge who had received instruction from the electrician and was authorised to reconnect the equipment, attempted to insert the plug. The plug would not enter the socket because the switch was on. The man was puzzled and, withdrawing the plug again and holding it in his left hand,

apparently inserted one finger in one of the contacts to remove some obstruction, fancied or real, and he was unfortunately killed.

The remedy for accidents of that kind was obviously the use of an electrical interlock; Mr. Horsley considered that where men untrained in electrical science had to remove and insert plugs in the ordinary course of their work, the electrical interlock would come to be regarded as necessary. There was provision in the British Standard Plug for an electrical interlock as well as or in substitution for the usual mechanical interlock with the adjacent switch. The electrical interlock of course would be associated with the switchgear at the outbye or supply end of the cable.

Mr. Hepburn had raised several very practical points. He invited views as to the desirability of sealing the dielectric of trailing cables. Mr. Horsley could say that in no plug with which he was familiar had provision been made for sealing the cable with compound at the point of entry. He was afraid that in many instances main cable junction boxes were not sealed. Mr. Horsley further agreed that gauging of air gaps in motors was of less value when ball or roller bearings were used because no wear was permissible.

Mr. Hepburn had advocated the regular testing of the automatic trips in a system and in that was perfectly right. It was troublesome to apply such tests because it necessitated bringing switchgear out of the mine; that was just the reason why some standardised system of coupling boxes would be extremely convenient. Mr. Horsley would take the suggestion even further; in testing leakage trip devices he would not be satisfied to put a leak upon one phase only but upon each phase in turn.

Commenting on the remarks by Mr. Brooking, Mr. Horsley said it was quite true that a considerable proportion of the accidents with trailing cables were due to men getting into contact with one live core. The screened type of cable therefore offered protection against such contact, but although he, Mr. Horsley, had been advocating the screened type of cable for ten years, he did not do so excepting when it was to be associated with leakage protection and in cases where the electrical staff were competent to undertake the repair of such cables. The screened cable was perhaps the more dangerous type of trailer when not properly maintained. Referring to Mr. Brooking's suggestion that ferflex suffered corrosion by free sulphur in the cab tyre sheath, Mr. Horsley would submit that corrosion by access of moisture was more to be feared, and was sure that the life of trailing cables could be considerably prolonged by paying strict attention to the repair of all incisions in the sheath before water had been allowed to enter or as soon as possible after the incision had been made. He had no doubt that careful attention to this matter would result in much better service from trailing cables.

Mr. Horsley agreed with Mr. Taylor that where there were relays it would generally suffice to test the operation of the relay by hand and to test the relay circuit *in situ* for continuity. He was thinking rather of such switchgear as is used near the coal face and which might suffer very rough usage. He quoted the instance which happened at a large colliery in which the relay was in order but the circuit breaker did not trip when a length of high voltage cable controlled thereby was destroyed by fusion. On the front of the switchboard there were dials for adjusting the trip setting and time lags but the accumulator that provided the power through the relay to trip the switch was missing and had apparently been missing beyond the memory of anyone then in charge of the electrical plant.

WEST OF SCOTLAND BRANCH.

Joint Meeting with the National Association of Colliery Managers.

A joint meeting of the West of Scotland Branch of the A.M.E.E. and the Scottish Branch of the Association of Colliery Managers was held in Glasgow in February 28th last. There were present Mr. R. Rogerson and Mr. D. Archibald, the respective presidents of the two branches; also the secretaries, Mr. W. G. Gibb and Mr. John George. In the beginning Mr. Rogerson presided whilst the routine business of the A.M.E.E. was in hand. The minutes of the previous meeting were adopted and Messrs. F. G. Shand and J. H. Neilson were elected members. Thereafter Mr. Archibald was invited to preside. He introduced Mr. David S. Harrison who read the following paper.

Double Unit Conveyor and Machine Mining in conjunction with Steel Supports for Roof.

D. S. HARRISON.

The double unit system of mining has been very successful in working the Wilsontown Main Coal Seam in Whitrigg Colliery. The working face is at a depth of 193 fathoms, and the particulars of this seam are as follows:—

The inclination is fairly flat with undulations here and there. The thickness of the seam is about 4 ft. with a band of greystone about 5 ins. thick running through the seam about 10 ins. from the pavement. Immediately above the coal there is from 6 ins. to 18 ins. of blaes and sometimes rock, above that from 20 ins. to 24 ins. of craw coal, and then about 6 ft. to 7 ft. of blaes to a rock post (see section Fig. 1).

The conveyor faces in the double unit are 100 yds. on each side of the main road, and are laid out to produce about 150 tons of coal from each side, with a 3 ft. 6 ins. undercut. This gives a total output from this section of approximately 300 tons per day. The coal is undercut by an Anderson Boyes 17½ ins. chain machine.

On the face to the left-hand side of the main road the coal is conveyed by a Huwood 20 ins. flat belt, and on the right-hand side by an Eickhoff shaker conveyor, having ball frame and Poxon rope attachments; these conveyors deliver the coal on to a 26 ins. flat belt conveyor, which conveys the coal to the loading station.

Fig. 1.—Section of Wilsontown Main Coal Seam.

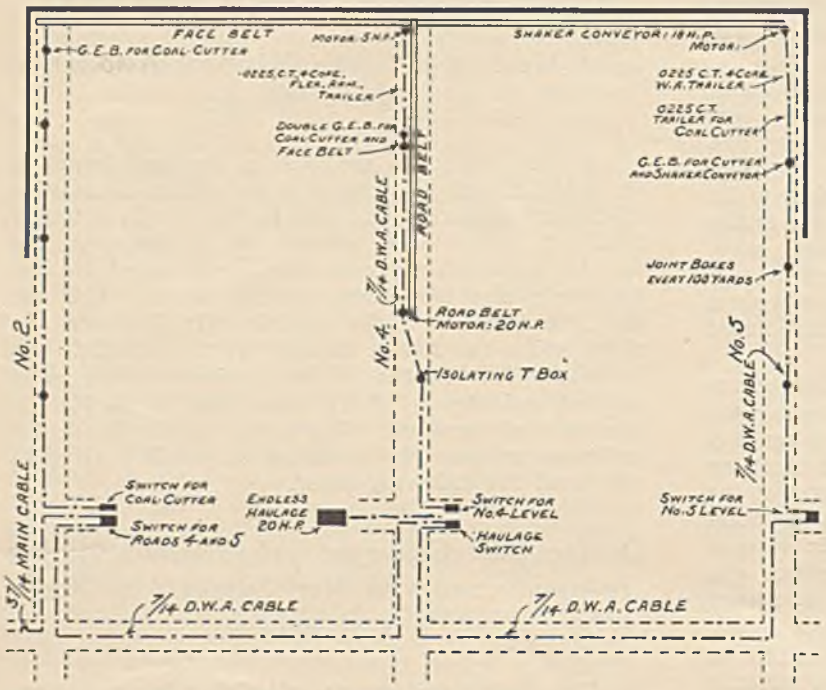


Fig. 2.

The face belt is driven by a 5 h.p. motor ; the shaker conveyor by an 18 h.p. ; and the road belt by a 20 h.p. motor. The cables and switches to control this section are all shewn in Fig. 2, which also shews the general layout of a double unit face line.

There are three roads brushed : the main road is brushed to allow 10 ft. wide and 8 ft. high circle girders on 18 ins. stilts to be erected, and the two end roads are brushed for circle girders 7 ft. by 6 ft. 6 ins. mounted on 18 ins. stilts. The roof at the face is supported by composite steel props 4½ ins. outside diameter by ¼ in. thick and corrugated steel straps 4 ft. long by 5 ins. by ⅜ in. thick. Packs are built 10 ft. broad with a space of 30 ft. between them, and are built at right angles to the line of the face.

To be successful the work must be carried out systematically. The system may now be described in detail.

The diagrams in Fig. 3 shew how the face should be standing at the start of each shift, and the process is divided as follows :—

(1) Stripping and prop setting on the day-shift.

(2) Cutting, spragging, pan shifting, brushing and pack building on the back-shift.

(3) Prop drawing, boring and blowing if necessary on the night-shift.

Day-Shift.

When stripping starts there is a single row of "sets" along the face, with the conveyor in the centre, as shewn in Fig. 4.

The strap, which in this case is 4 ft. long, is placed at right angles to the coal face with its faceside end

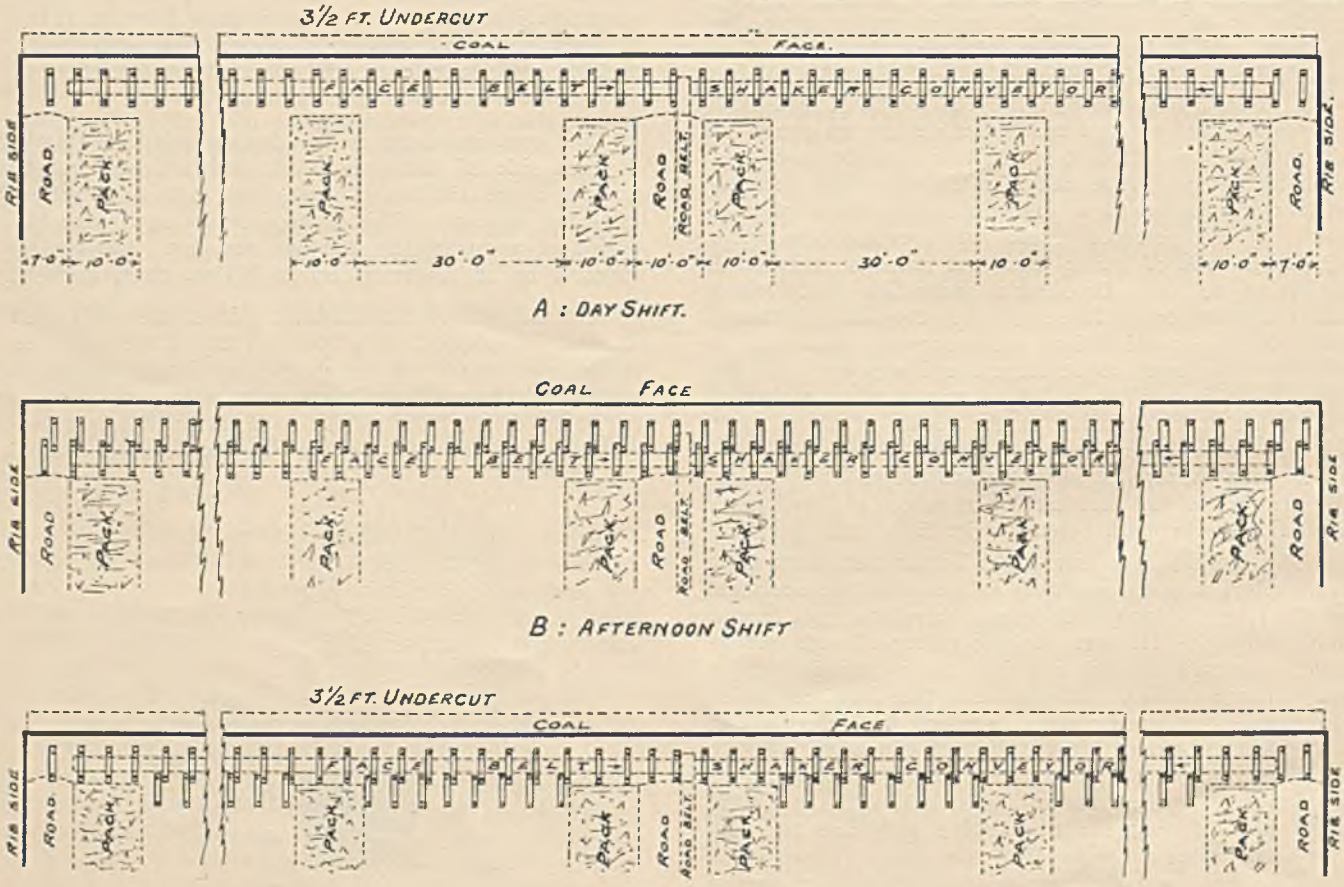


Fig. 3.

2 ft. off the face. The faceside prop is put to it 2½ ft. from the face and the wasteside prop placed at the extreme end of the strap which brings it to 3½ ft. off the face prop. The conveyor occupies a central position between these two props, all as shewn in the sketch, Fig. 4. The "setts" are placed 3½ ft. apart. The strippers are ranged along the face at such intervals as to allow of the entire face being stripped in the one shift while giving each man his full quantity of coal. As soon as a stripper has filled sufficient coal to allow of it, he must at once erect a new "sett", which is done in this manner :—

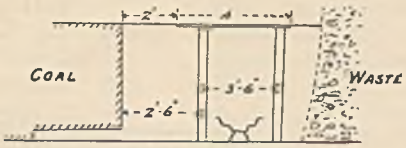


FIG. 4.

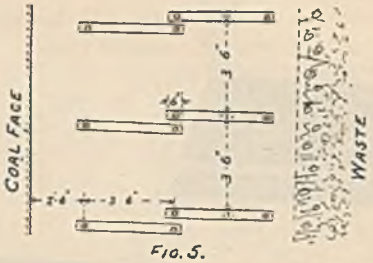


FIG. 5.

FIG. 6.

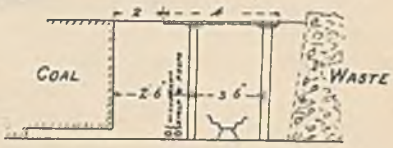


FIG. 7.

A strap is placed in line and overlapping by 6 ins. with the existing one, and just "blind" of it. The wasteside prop is placed at the extreme end of the strap and the faceside prop 3½ ft. inside it (Fig. 5).

The props are not placed vertically but are given a rake towards the wasteside of from 1 in. to 2 ins. The 3½ ft. spacing between "sets" must be rigidly adhered to. If the roof conditions call for it one or more extra "sets" can be placed between and in line with the standard "sets". At the completion of the day-shift the face must be completely stripped and the second "sett" of props standing in position as shewn in Fig. 6. It is important that the "setts" be placed in a dead straight line up and down the face so as to allow of the conveyor being laid straight.

Back-Shift.

The face is now ready for cutting, which proceeds in the usual manner ; the machine-man wedging up the cut opposite each "sett" as the machine passes along. Brushing and pack building are done on the back-shift along with the coal cutting, and the conveyor moved to its new position.

Night-Shift.

The drawing of the props is started. In this operation the following method must be carried out. Two sylvesters are supplied to each prop-drawing squad. The chain of one sylvester is made fast to the top of the wasteside prop of the "sett" to be removed. If the roof is sound the faceside prop is then knocked out after which the loose end of the strap is knocked from side to side after which a pull on the sylvester chain brings the wasteside prop away. If the roof is not sound the second sylvester chain is attached to the top of the faceside prop and both props pulled out by the sylvesters, the wasteside prop first. The props and straps as they are withdrawn are placed on the faceside of the standing "sett" as shewn in Fig. 7. All damaged props or straps are sent to the surface by the section fireman, with a note to the pitheadman stating how many are sent up and how many must be returned to the section.

At the siding, props, straps, and lids are continually kept in reserve. The section fireman is responsible for the correct setting of the standard propping, and also any extra propping that safety calls for. He is also responsible for all damaged props and straps being sent to the surface and being replaced by sound ones and that no loss in numbers takes place. In putting up the "setts" the strap is placed against the roof, then wasteside prop is put to it with a lid between the strap and the prop ; the faceside prop is set in like manner.

The lids will be of varying thicknesses so as to compensate for the variations of roof and pavement. All the props must have a hang in the head towards the waste of from 1 in. to 2 ins. as before stated so that the subsequent roof movement brings them to the vertical position by the time they are due for drawing. In the interests of safety and efficiency it is necessary that these instructions are rigidly carried out.

The number of workmen employed in carrying out this work in the section is as follows. Twenty-one strippers, who strip coal, put stone into waste, and sett steel props ; two hole-borers ; four machinemen ; five brushers ; six pack-builders ; four prop-drawers ; six men for pans and belt ; one for road-belt ; seven on-cost workers, who look after conveyors, supply men with steel props and do repair work ; and four for loader. The whole makes a total of sixty men. The output per man on to the haulage road is approximately five tons.

Labour Cost on to Haulage Road.

	s.	d.
Stripping, boring, redd dirt, sett steel props, and explosives (contract work)	1	0
Coalcutting (contract work)	0	2.75
Brushing, 70/- per fm. for Main Road, and 20/- per fm. for End Roads (contract work)	0	2.60
Pack-building at 68/- per cut (contract work)	0	2.72
Prop-drawing at 44/- per cut (contract work)	0	1.76
Pan-shifting and extending road belt at 72/- for face pans, and 11/- for road belt (contract work)	0	3.32
Oncost, 7 shifts at 8/4¾ per shift	0	2.36
Loading (contract work)	0	1.50
	2	5.01

giving a total of 2s. 5.01d. per ton, or, say a cost of 2s. 6d. per ton loads the coal into the hutch.

Approximate cost of steel props and straps is 1.50d. per ton of coal

Approximate cost of circle girders is 2.75d. per ton of coal

General Observations.

In the working of this face, difficulties were encountered which are worthy of note.

(1) A 7 ft. 6ins. downthrow fault was struck at the extreme right end of coal face, which meant that the coal face would be gradually cut off, if it was not cut over in every shift. It was decided to cut it, and there has not been a shift lost, while this fault has travelled across 100 yards of the coal face. The angle at which

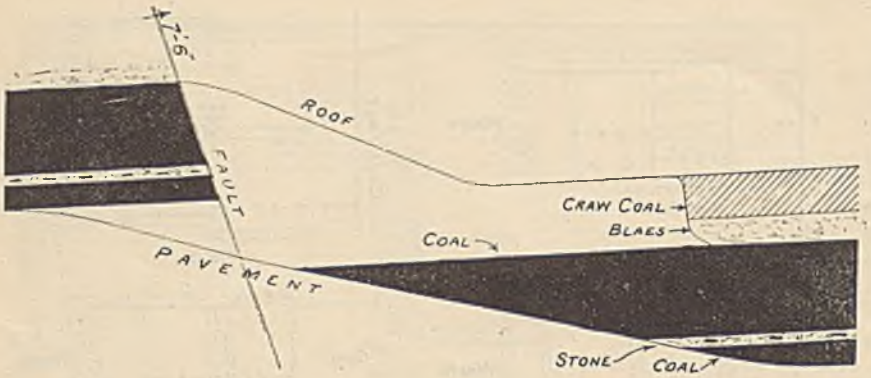


Fig. 8.

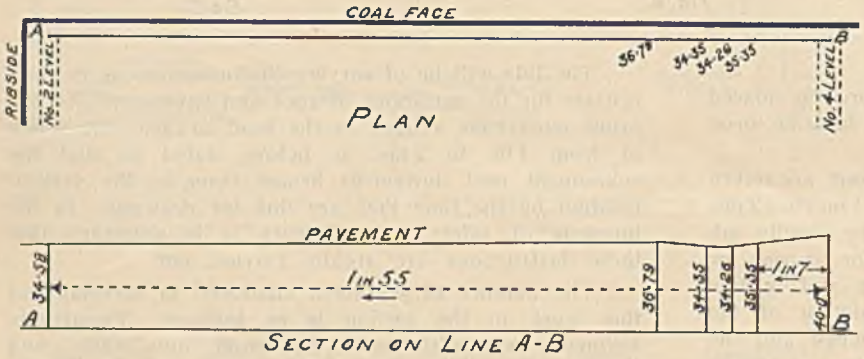


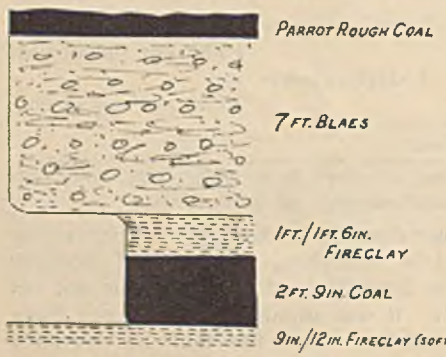
Fig. 9.

this fault was running caused the loss of about 5 ft. to 6 ft. of coal per day. The fault was graded out (see Fig. 8), which allowed the machine to cut and the conveyor to work satisfactorily.

This extra work added 4d. per ton to the sectional cost.

(2) On the left face an undulation came in, which altered the contour of the track metals, and it was necessary to jig the coal uphill with an average grade of 1 in 55 (see section Fig. 9). It is interesting to note that under these abnormal conditions the coal was conveyed by Eickhoff jigger conveyors fairly satisfactorily without loss of output. When conditions such as these prevail it is better to have some form of positive conveyor, either belt or chain; hence the reason for installing the belt conveyor on the left side of section, but where conditions and grade are suitable the author prefers the jigger conveyor.

(3) The main road was undulating badly, so that work could not have been carried on without a road conveyor and a fixed loading station. For road conveyor work under these conditions the flat belt is preferable.



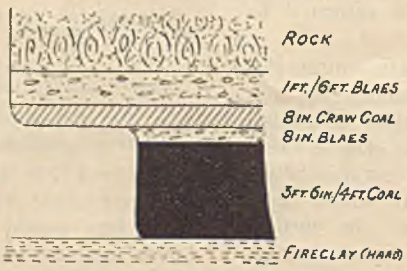


Fig. 10.—*Section of Jewel Coal Seam.* *Fig.* 11.—*Section of Rough Coal Seam.*

Some persons are inclined to say that this system of mining is alright where conditions are suitable. The author agrees but, further, is prepared to hold that in a number of cases where the conditions are below the average, if this system of mining were adopted, those persons would be agreeably surprised at the results.

Typical Working.

The following describes the conditions in two different seams at another colliery where the author was manager, and were this system of mining was remarkably successful.

(1) In the Jewel Coal Seam the particulars of which are as follows (see Fig. 10) :—

9 ins. to 12 ins. soft fireclay pavement.

2 ft. 9 ins. coal.

1 ft. to 1 ft. 6 ins. fireclay (good for making bricks).

7 ft. blaes to parrot rough coal.

Under ordinary mining it was impossible to keep roads due to the soft pavement, in fact there were 7 ft. steel props (supporting girders) which had sunk into the pavement until only 2 ft. of the prop was exposed; and those props were on soles 1 ft. square.

A bar machine was cutting in this section and it could only cut one or two places per shift due to it sinking in the soft pavement. The author put in an Anderson Boyes chain machine with full size bottom plate, straightened up the coal face, built packs; installed conveyors, steel props, circle girders in the roadways, and from the face of 100 yards long approximately 100 tons of coal was produced per shift, plus 60 tons of clay, which went to the brickworks.

(2) In the same pit in the Rough Coal Seam the particulars are as follows (see Fig. 11) :

3 ft. 6 ins. to 4 ft. coal.

8 ins. blaes (this was filled for brickwork).

8 ins. craw coal (this formed the roof).

1 ft. to 6 ft. thick blaes up to rock post.

Under ordinary mining about every fortnight the roof took a break resulting in some closed places and crushed roads. Conveyors and steel supports were installed eliminating part of roof trouble, but not entirely, as at this period packs were not built. Under this system there was still some trouble with the roof, and latterly it was decided that packs should be tried; they were very successful in making the roof better. In the author's opinion one of the most important factors to make this system of mining a success, is the building of efficient packs to control the roof. In Whitrigg Colliery there has not been a cut of coal lost due to roof trouble in conveyor runs for two or three years back.

In conclusion and in summing up, it is absolutely essential that the organisation and maintenance be kept

to a high standard. Regular inspection of all machinery helps to eliminate breakdowns. Haulage arrangements must be adequate to deal with the coal produced. Though this system of mining has been considered a failure in some collieries, the author is convinced that the failures have been due to no other reason that tha the arrangements for taking away the coal were inadequate. These notes have purposely been made as practical as possible in the hope that they would be the more interesting and generally useful.

Discussion.

Mr. ROGERSON congratulated Mr. Harrison on his very interesting and instructive paper. He had given exceptionally valuable details even to output per man-shift and costs of production to the haulage road. Regarding steel props, one of the chief factors in their effective use, said Mr. Rogerson, was the observance of the propping regulations as laid down by the manager. It was most important that close observance of these maximum propping distances be followed out by those responsible. With greater regard given to those regulations, many of the accidents due to falls of roof at the working face might be avoided. It was a well known fact that about 50% of the total accidents that occurred were from falls at the face. That was not due to any lack of intelligence on the part of the miner, or to the lack of supervision or guidance, but could be more fairly attributed to the indifferent attitude of the miner as to the dangerous nature of his work. He would ask Mr. Harrison whether he could give any comparative figures as to the relative costs per ton of steel props as against timber, over a period of say twelve to eighteen months? He would also ask what method Mr. Harrison used for checking the loss in steel props and the approximate percentage loss?

Mr. DOUGLAS BAIRD.—Mr. Harrison's paper is an extremely useful and practical one, its only defect, if defect it be, was being that it seemed to make an exact and difficult piece of work appear so simple. The author had encountered many difficulties in the face, not the least of which was a seven feet fault: a difficult proposition which would have deterred many from attempting to cross it with conveyors. Mr. Harrison had not only crossed it, but had crossed it so successfully that no cuts were lost, and did the work at very little cost. That was a feat of which Mr. Harrison might justifiably feel proud.

By building packs and cutting out brushing, Mr. Harrison appeared to have effected a saving of about three pence per ton; brushing costs usually run from eight pence to ten pence per ton.

Was reliance placed entirely on the "grey stone" in the coal for the packs, or was this stone supplemented with stone from the closed roof?

Under certain conditions an ordinary machine mining face could sometimes approach pretty near to the cost and output per man of conveyor mining. Mr. Baird said he had in mind a machine section in the same seam that Mr. Harrison was working, where the cut coal was stripped and loaded into hutches, and drawn to the eye at the haulage road by hand, with the drawing roads brushed every forty feet or so. The men employed were twenty-eight strippers, three machinemen, and eleven brushers, a total of forty-two men for an output of 220 tons: equivalent to an output per man of 5.24 tons. The face was supported by wood which was not withdrawn: so that, deducting the four men drawing props from the face dealt with by Mr. Harrison, the corresponding figures would be fifty-six men for 300 tons, an output per man of 5.36 tons. The figure 5.24 tons for ordinary machine mining, compared very favourably with the 5.36 tons for conveyor machine mining. Of course, the cost of the wood, and the upkeep of the drawing roads, the rails, etc., would need to be added; but, on the other hand, there was the cost of the equipment for the conveyor face and road which was sure to be heavy. It may, however, said Mr. Baird, be a very exceptional case which he had quoted. Despite these criticisms, Mr. Baird expressed himself as fully in accordance with Mr. Harrison's advocacy of conveyor mining with steel supports. It had become an established economic success, and was beyond the experimental stage.

Mr. A. F. STEVENSON said he noticed that the cable to the conveyor motor was of the C.T.S. type. Many engineers were now using a semi-flexible armoured cable for this purpose, the armouring being composed of seven strands of wire laid on sparingly and not braided. This had been found desirable as the C.T.S. covering was liable to be cut by tools and other sharp materials being thrown on to the coil. The usual practice was to flake down the cable in a figure eight coil at the box at the end of the permanent cable and to pay out the trailer as the conveyor advanced.

Mr. J. McD. WILLIAMSON.—Mr. Williamson asked Mr. Harrison to give particulars of his experience in using circle or arch girders at the face in a four-foot seam with eighteen-inch stilts; also the section of girders used, and the distance they were set apart; also if the arch girders were damaged or distorted with the roof movement, and if so, to what extent were they damaged?

Mr. MURRAY.—Mr. Murray asked if cutting would not be better done in the night shift as it appeared there might be danger due to shifting pans and coal cutting on the same shift; moreover, it seemed that coal cutting would be better done after the packs were built.

Mr. JAMES R. LAIRD.—Mr. Laird asked whether the switches for the three motors were interlocked in sequence so that the motors and their units started in proper order. He would also like to know whether the shot holes were drilled with electric drills, and if so, what types of machines were used.

Mr. J. B. MAVOR (communicated).—I have read with the greatest interest Mr. Harrison's able Paper on the subject of Double Unit Conveyor and Machine Mining in conjunction with steel supports for roof, and much regret my inability to be present at the Meeting.

There are one or two points in Mr. Harrison's Paper on which I would like to make comment. It is noted that Mr. Harrison is using a flat belt in the roadway conveying 300 tons per shift; a 26 inch belt is used and it is driven by a 20-h.p. motor. I should be interested to know the construction of the belt mentioned. Mr. Harrison does not state the number of plies or the weight of duck used therein. It would also be of great interest to know the speed at which the belt is running, the average gradient, and the maximum length to which he intends to run the belt.

The power, 20 h.p. appears to be very excessive power for the output being conveyed. It is stated that the road is undulating, and if the mean gradient is approximately level a smaller belt and very much less power would be used if the troughed construction of conveyor were at work. Assuming the average gradient of the road to be level, the power required to convey 300 tons a shift, or a peak load of 75 tons an hour is only 2½ h.p. per 100 yards run. In this one respect, the writer entirely differs with Mr. Harrison in that,

with outputs of 200 tons and over, the flat belt is undoubtedly not a suitable appliance to use for gate-road conveying, and would like Mr. Harrison to give an estimate of belt life and cost per ton on his gate-road conveyor. The writer's experience does not permit of an estimate of belt life with a properly designed troughed belt conveyor when used underground, as he does not know of one in this country which has run for a longer period than four years, but the belts which have run for this period are still in good serviceable condition, and it is possible now to procure guarantees from the belt makers which ensure that the replacement of the belt when its life is completed will cost less than a halfpenny per ton over the whole output.

Individual cases must always be considered with such guarantees, and the writer is confident that such a maintenance cost cannot in the best conditions be attained by a flat belt with side plates, which it is presumed are used in Mr. Harrison's case. A properly designed troughed belt, with adequate provision made for loading at the receiving point, is the most economical and simple piece of mechanism which can be put in the pit. There is a fallacious notion creeping into the mining industry that the troughed belt cannot be controlled to run true and, as a result, causes spillage. A troughed belt conveyor which cannot be controlled to run true is a wrongly designed conveyor. Actually, though it is a practice not to be condoned or encouraged, a well-designed troughed belt conveyor can be made to run with the belt central on the idler rollers when the tail pulley is 3 ft. in every hundred yards, out of line with the head pulley. What flat belt conveyor could possibly meet these conditions without entirely destroying its belt?

Mr. HARRISON (in reply).—The reasons for the shallow depth of undercut were: when fixing the depth of undercut to be worked with it was duly considered whether it would be better to have a short coal face with a deep undercut or a longer face with a shallow undercut. The decision rested with the latter, as roads being difficult to maintain, it entailed the use of fewer roads for a given area.

Sometimes there was only 4 ins. to 5 ins. between the ground coal stone and the pavement, so that with a longer jib there was more chance of catching stone even if the jib were very slightly tilted.

The maximum length of road belt was to extend 300 yards; the belt was composed of five-ply with rubber 3/64 in. thick, top and bottom.

Mr. Harrison prefers the flat belt because where the coal is large there is an excessive spillage from the trough belt, and the same applies to trough loaders. There had been no renewals required for the road belt so far. As to costs he was not yet able to give useful details.

In reply to the comments by Mr. Baird, the packs were built with the best materials obtainable, and both ground coal stone and roof were used. As to the statement that under ordinary mining Mr. Baird had almost 5 tons per man; that was sometimes a question of conditions, but, in Mr. Harrison's opinion, the figure could be improved under the system of mining described.

In reply to Mr. Stevenson, it was to be noted that M. & C. Froid trailing cables were used, and that those cables were flexible armoured.

The section of girders used at face was 5 ins. by 3 ins., but where back-brushing was in operation 5 ins. by 4½ ins. was used, as the former section was too light. In some cases stilts were not the success looked for, due to excess side pressure and that reduced the width of the road, although the height was fairly well maintained.

While Mr. Harrison considered that coalcutting on the night-shift would be better, due to the reasons put forward by Mr. Murray, he thought it preferable to cut on the afternoon shift, as it gave more time on hand in case of a breakdown. Also, where this system of mining was adopted, and taking into consideration the thickness of the seam, there was really no danger in the two operations being done on the same shift.

In reply to Mr. Laird, there was no automatic sequence or interlocking arrangement. Signalling apparatus was fixed along the coal face so that when the road belt was stopped, the attendant received the signal to stop the face conveyor. There was no electric borer on this coal face, but there were two electric borers in operation on other faces. One man bored an average of sixty holes per shift.

£100,000 CONTRACT FOR BOILER DRAUGHT AND DUST COLLECTOR PLANT.

Davidson & Co., Ltd., of the Sirocco Works, Belfast, have received one of the largest contracts for mechanical boiler draught and flue dust collector equipment that has ever been placed in the British Isles. The value of the contract exceeds £100,000. The equipment is for the new power station of the Newcastle-on-Tyne Electric Supply Co., at Dunston-on-Tyne, and a substantial part of the plant will be manufactured on the Tyneside, and will thus benefit local industry.

The boiler plant for which this installation is intended, comprises twelve units, each capable of generating 156,000 lbs. of steam per hour. Eight of the boilers will be fired by mechanical stokers and the remaining four will be fired with pulverised fuel. The boilers will be arranged in three groups of four, each group supplying steam to a turbo-alternator set of 50,000 k.w. capacity taking superheated steam at 625 lbs. per square inch working pressure and at a temperature of 840 degs. F.

The mechanical draught plant is to comprise forty-eight electrically driven "Sirocco" fans, twenty-four for forced draught and the other twenty-four for induced draught. All the fans will be driven by direct-coupled totally enclosed motors of the squirrel cage single speed type, and provision is to be made for applying variable speed hydraulic couplings of special design which will enable the speeds of the fan shafts to be varied as required, according to the boiler loads, with the motors running at constant speed. Thus, the motors can be thrown directly on to the electric supply and started up under practically no-load conditions; the load is applied gradually by increasing the speeds of the fan shafts after the motors are in operation and running at full speed.

For eliminating the dust and grit from the flue gases, seventy-two Davidson patent direct type flue dust collectors are being supplied in groups of six collectors per boiler unit. The flue gases will be passed through the collectors before reaching the induced draught fans, thus all abrasive matter is extracted before they reach the fans, and there is no possibility of trouble due to the erosion of the fan casings and runners.

The dust extracted by the collectors will pass into large airtight dust receivers capable of holding the total quantity of dust extracted during twelve hours' continuous operation under maximum load conditions and the dust will be removed periodically from these receivers by special ejector equipment.

The contract includes the provision of a regulator equipment arranged to control the draught in the boiler furnaces automatically by varying the speeds of the induced draught fans through the hydraulic couplings. The forced draught fans will operate at pressures up to 10½ inches W.G., whilst the induced draught fans will be required to operate against resistances up to 12¾ inches W.G.

The whole of the work is to be carried out under the superintendence and to the satisfaction of the Newcastle-on-Tyne Electric Supply Company and their consulting engineers, Messrs. Merz and McLellan to whom acknowledgments are due for permission to publish these details.