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The Song of the Grid.

Most folk will agree that whatever the skilful engineer designs is of necessity possessed of the elements of beauty. Balance and rhythm, flexibility and strength, are got by blending and proportioning matter and material in conformity with natural laws and the result is pleasing to the senses of the normal natural man.

A transmission line with its aerial filaments perfect and graceful in curvature may be, firstly and at the worst, incongruous in the heart of the Lake District but, later on, there will be those who will enthuse on its beauties. Hear already how the people rhapsodise about the beauties of the motor car, the aeroplane, the ocean liner, the embankment, and the innumerable encumbrances with which man as a civilised being has so recently embellished the earth, the air, and the vasty deeps, to his greater happiness.

The public outcry against atmospheric pollution is quite another matter: the destructive dirty and unhealthy effects of the fire and furnace have hitherto been tolerated as a part of the price to be paid for the greater gain. We now know of means to avoid that payment and we act accordingly. The "grid" is one of those means. Who will venture to say that it were better to live all the year round in a fog enveloped town than to have a transmission wire spanning the moorland? Who will say that it were better to gather all the young folk of the kingdom into unwholesome murky hives of humanity rather than to bring to them in the wide countryside this same electric transmission as the means to live as men should live and prosper ?

It is indeed very difficult to speak politely to those who condemn the "grid" as a fancied blot on the fair face of the earth. The earth will smile more cleanly and brightly for everybody when it is cleaned of the smoke of industry and bedecked with this graceful gossamer of modern power. Once upon a time men despoiled nature by throwing an ugly dam of masonry across the sightsome brook and reared a monstrosity of a mill with a creaking groaning wheel to disturb and deface the landscape. Then, after a while, the poet and the artist found them good. Who will sing the Song of the Grid ?

Super Tension Underground.

The paper by Messrs. W. Elsdon-Dew and H. Denehy read in Johannesburg last July before the South African Institute of Electrical Engineers is extremely valuable from many points of view. The lengthy abstract of which the first part is published in this issue covers only a few of the main considerations introduced in the original paper.

The broad minded and well informed policy of those responsible for the Rand mines is commended. The electrification of the gold mining industry, which was definitely decided in 1909 has been a marvellous success. The earlier part of the paper under review, by figures and records proves the economies and flexibility of heavy power transference to be such that the industry could not have continued and developed without electricity. Thus in course of time it came about that the 2,000 volt distribution pressure had reached its economical limit; deeper shafts, more remote workings, heavier outputs demanded ever more and more power over wider areas and greater distances.

The historical introduction to the technical part of the paper shews that the usual incentive to progress—sheer necessity—drove the engineers to greater things. It was apparent in 1923 that the need for heavier power services underground demanded a degree of economy combined with close regulation of electrical distribution impossible to obtain with voltages of 2,000 or so. Then comes the usual story of the apathy of manufacturers. The cable makers were not disposed to tackle the problem of making supertension cables, for about 20,000 volts, for installation in hot mine shafts several thousand feet deep. So it was that the equipment of these mines was delayed some two years. In the meantime the cable makers had successfully tried their hands at making super tension street mains for public supply use.

It is significant to note that the British firm which did eventually do the work in the Crown Mines, voluntarily offered guarantees better than those stipulated in the purchasers' specifications. The rapid change from apathy to excessive zeal is rather difficult to explain but it can at any rate be accepted as a good sign and, in conjunction with the resultant complete success augurs well for great future developments in the use of electricity underground in mines.

Research work ultimately revealed the basic causes of high pressure cable failures. The stress limits, both mechanical and electrical, were closely defined in terms of materials and methods of manufacture. It was proved that the method of manufacture of paper insulated cables was the ruling factor limiting the maximum voltage which could with safety be employed for continuous duty. Briefly stated, imprisoned air and thin-running impregnating fluid had to be eliminated. The problem was therefore mainly one of new mechanical means of manufacture. It was obviously impossible to exclude air from being trapped in the lapping of paper strips by means of the usual revolving carrier of a group of paper spools spinning around the conductor fed forward from the cable drum. At the moment of applying the paper and impregnation to the conductor the length being served must of necessity be fully submerged in the impregnating compound. The usual process was therefore reversed and the heavy cable drum of conductor was mounted in a massive rotating cage from which the spinning conductor was drawn forward through a bath of compound down into which the paper strip or ribbon was drawn from fixed spools above the bath on to and by the spinning conductor or core. Furthermore, this arrangement permitted the use of a hot application of the impregnation; the bath being heated a compound can be used which is solid at normal temperatures, and thus the bleeding of oil, that great drawback of paper-oil cables, is entirely eliminated. Here then is the method of making a perfect mine shaft cable, irrespective of the voltage or other circuit conditions. This all seems quite simple, but one must consider the speculative risk and heavy expense involved in building the massive machinery and give credit to the British firm responsible for this highly successful revoluntary departure from normal established practice.

To the mining engineers of this country the Rand Crown Mines installation brings home the lesson that there are still greater economies and advantages to be got by the more extensive use of electricity below ground than they have as yet considered possible. As to safety the authors of this paper stifle argument by indicating, rightly, that 2,000 volts and 20,000 volts are equally fatal; in practice it is expected that the higher pressure will, if anything, be safer because of the precautions introduced in view of its greater potency. The safety or protective methods adopted on this system are discussed in detail in the paper; they are evidently altogether adequate and dependable. A general outline of the provisions made will be included in the second abstract in our next issue.

NEW BOOKS.

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

Mines Department.—LIST OF MINES in Great Britain and the Isle of Man: Year 1928. Price 18s. 6d. nett.

Mines Department.—REPORTS of H.M. Inspectors of Mines for the Year 1928. Price, each, 1s. nett.
No. 2.—Northern Division: by Mr. T. Greenland Davies.
No. 3.—Yorkshire Division: by Mr. H. M. Hudspeth.
No. 4.—North Midland Division: by Mr. J. R. Felton.
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No. 6.—Cardiff and Newport Division: by Mr. J. MacLeod Carey.
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Mines Department.—SAFETY IN MINES RESEARCH BOARD. Seventh Annual Report, including a Report of matters dealt with by the Health Advisory Committee. Price 1s. nett.

Mines Department.—METALLIFEROUS MINES AND QUARRIES. Reports of H.M. Inspectors of Mines and Quarries for the Year 1928. Price 1s. nett.

Mr. J. C. Fox, the Managing Director of the Stanton Ironworks Company Limited, has joined the Board of Messrs. Crompton Parkinson Limited.

Batteries in Winter.

The annual lunch given by Exide Batteries on the occasion of the opening of the Motor Show took place at the Clarendon Restaurant on Thursday the 17th October, 1929. Mr. D. P. Dunne, director of the Chloride Electrical Storage Co., Ltd., in the course of a short address of welcome, gave some useful hints on the care of batteries during the winter months. If the battery is to be used during the winter one serious danger that may arise is from frost—14 degrees Farenheit of frost are required to freeze acid 1.100 specific gravity, 27°F. to freeze acid 1.150 sp. gr., and 50°F. of frost to freeze acid 1.200 sp. gr. Above that density batteries are immune from freezing in this country. The gravity of the electrolyte should therefore be kept well up. The way to do this and to guard against frost is to see that the plates and separators are always covered by the electrolyte, while the battery should be given plenty of charging, particularly if the car has been standing with lights on for lengthy periods. If the electrolyte is low, add distilled water, just covering the plates and separators with it. It may not be sufficient however, merely to pour in water to bring up the level, as the water will not mix with the acid unless stirred up by the charging.

The moral is (1) Always keep the plates well covered with electrolyte during extreme cold. (2) Ensure thorough circulation and mixture of the water and acid by giving the battery a charge after every addition of water.

If the battery is to be put away for the winter, it should first be fully charged. It can then be kept in condition for immediate use by giving it a freshening charge, say every two months: and it should be given a thorough charge at the end of the winter before it is again brought back into service. It is not wise to permit a battery to stand for more than three months without charging.

The Protection of Circuits and Apparatus against Excessive Current.

F. MAWSON.

(This is the seventh of a series of Articles intended more particularly to help Students and Junior Engineers: the preceding Article appeared in the August number).

THE primary object of protection devices is to prevent damage if possible, and failing this, to cut down the extent of the damage also at the same time maintaining, wherever possible, all parts of the system in operation with the exception of the section which is directly affected by the fault.

Excessive current may be the outcome of:—

(a) Too low a resistance, when the overload becomes a maximum because the resistance has become a minimum, i.e., in the case of short-circuit.

(b) Excessive pressure.

The simplest means of safeguarding against excessive current is to take advantage of the heating effect of a current. By inserting a wire in the circuit, of suitable material and cross-section, so that the heat produced (I^2R) in this portion of the circuit will, at a predetermined value of the current, be sufficient to melt that wire. Such a device is called a fuse.

The materials commonly used for fuses are tin or a low melting point tin alloy, on account of the specific resistance being high and thus the diameter of fuse required for a given current is much greater than would have been the case if copper fuses were used.

Fuses are not generally employed in three-phase circuits as the fuse may melt in one phase only: that would thus leave the circuit alive, and the apparatus may continue to work on two phases only, taking excessive current. It is usual therefore to employ circuit breakers in A.C. work, other than in single-phase circuits.

Fuses are chiefly employed in domestic circuits. The type of protective device generally employed in D.C. work is one which takes advantage of the magnetic effect of a current, viz., the passing of the current, or a definite portion of it through a solenoid, thereby creating an electro-magnet which can be made to operate a suitable switch or circuit breaker mechanism to open the overloaded circuit. An example of this type is the device usually found incorporated with face-plate starters, and generally known as the "overload release."

Taking advantage of the fact that increased current causes increase of flux, it is possible to construct an electro-magnet of such proportions that its strength varies according to the current passing through its coil. By having iron pieces of suitable weights, the force of attraction between the magnet and the iron can be so made use of that at any predetermined current the iron is attracted by the magnet and, in its movement, made to create a short-circuit in the "no-volt" coil, causing it to lose its excitation, and thus allowing the starter handle to be pulled back to the "off" position by the spring fixed for that purpose.

This principle is also made use of in connection with double-pole circuit breakers, and can be used either with or without a relay. When used on low or medium current circuits, the overload coil is placed in series with the main circuit, and the armature of the coil, which is attracted by the coil when the excessive current is passing, trips the switch, thus breaking the main circuit. In this case the overload coil also acts as the trip-coil.

When used in conjunction with a relay, which consists of a small circuit containing a "trip-coil" and battery, the attraction of the overload armature completes the relay circuit, which in turn causes the trip-coil armature to be attracted thereby tripping the switch. The advantage of the relay circuit is that it can be made much more sensitive. These overload and trip-coil armatures are adjustable so that they can be set to act at any required current.

Where, in A.C. circuits, the current necessitates a thicker conductor, and thereby makes the winding of a trip-coil (to be connected in series with the main circuit) more difficult, or high pressure causes the insulation to be of such thickness as to make coil winding difficult, a small current transformer is used to which an ordinary trip-coil is attached.

This automatic circuit breaker method is suitable for both D.C. and A.C. circuits, and in the case of the former and of single-phase A.C., only one breaker is required. In three-phase circuits it is insufficient to provide one circuit breaker. Two breakers must be provided when the neutral is insulated, and three when the neutral is earthed.

The foregoing remarks refer to automatic circuit breakers acting instantaneously, and it will be seen that even in the case of only a momentary excessive current they would operate. In many cases a momentary or short period "peak" of excessive current is an inherent characteristic of the load, or it is permissible as involving no risk: immediate cut-off is therefore not required, but it is positively to be prevented. Automatic circuit breakers with delayed cut-off are essential for ensuring the continuity of service under widely fluctuating loads opinion is against raising the test pressure inordinately and, though the specification called for an excess pressure test of 40 k.v. on all lengths for one hour, the manufacturers put forward the alternative of 60 k.v. for 15 minutes, which was accepted and successfully applied.

It was also specified that a breakdown pressure test should be applied to the sample used for the bending test (the latter to be carried out in accordance with the B.E.S.A. Specification No. 7 of 1926), and that the sample should withstand 80 k.v. for 15 minutes, after which the pressure was to be raised to the destructive point and the rupturing voltage submitted.

The manufacturers elected to increase the stringency of this by subjecting a sample to this test from one of the lengths previously heated for the power factor/temperature test, and at the same time guaranteed a sample previously heated as above, but not subjected to the bending test, to withstand a pressure of 100 k.v. for 15 minutes. These two tests were successfully carried out, the breakdown pressures being 128 k.v. and 149 k.v. respectively.

The usual requirements respecting the copper conductors, lead sheath, armouring and insulation resistance were specified ; as also self induction, and capacity tests, and these call for no comment ; but the collaboration of cable manufacturers was solicited in the specification to offer any such other suggestions which, from their experience in the manufacture of supertension cables, would enhance the success of the proposed installation, and particular attention was called to the question of hydrostatic pressure and the consequent danger of migration of the impregnating fluid.

Messrs. W. T. Glover & Company made the following recommendation, which was accordingly embodied in the order :—" A sample of cable, two yards in length and in its lead-covered state, shall be subjected to the following tests for bleeding :

" The length shall be suspended vertically and then heated by means of a current of 200 amperes (a.c.) passed through each of the conductors while the lead sheathing is maintained at a temperature of 100°F., either by means of suitable lagging or by enclosure in the heated vessel.

" The temperature of the lead sheathing shall be indicated or measured by a thermometer placed in contact with the lead and in the middle of its length.

" The total amount of compound which shall bleed from the cable when it has been continuously maintained under the above conditions for seven days shall be less than three grammes."

It is to be noted that this test would reproduce a thermal gradient in the cable similar to that under service conditions, but would represent the effect of about 6,800 k.v.a. instead of the proposed 6,000 k.v.a.

During the test the current was actually maintained at 205 amperes and the temperature of the lead at 102°F. as against the specified figures of 200 amperes and 100°F. respectively. The amount of bleeding was reported by the inspecting engineers to be negligible. (It is to be noted that the amount of bleeding in a similar cable supplied for a local mine by the same cable makers and tested similarly was absolutely nil.'

Also, at the instigation of the manufacturers, all cables in their lead-covered state were subject to a hydraulic pressure test of 60 pounds per square inch, by being completely immersed in a hydraulic pressure tank. It will be recognised that this test is much more stringent as a means of detecting incipient faults in the lead sheath than the more usual immersion in open water.

There remains but one other point to be noted in the specification, and that is the one that takes care of the " long-period " faults, to which reference has already been made. Cable manufacturers were required to guarantee the continuance and successful operation of the system for a period of five years from the date of satisfactory pressure test *in situ*. The contractors showed their confidence in the goods offered by accepting this condition up to the full value of the whole of the materials supplied.

It will be of interest to quote in Mr. Beaver's own words, a description of his prior-impregnation method of cable manufacture which he has employed for the past 30 years :—

" The primary difference between the Glover method of making impregnated paper cables and the common vacuum *en masse* method is, and always has been, that in the Glover process the paper is impregnated in sheet form prior to its application to the conductors instead of *en masse* as in the post impregnating process. This not only ensures that every part of the dielectric has exactly the same treatment, but also gives the advantage which is fundamentally important for the purpose under review : that the impregnation process is unfettered by any viscosity limits of the impregnating medium. The single sheet of paper passing through the impregnating machine receives a preliminary drying, and then passes through compound at a definite rate, i.e., providing a definite time of exposure to the air and moisture expelling action of the hot compound."

" The facilities for this purpose are very ample, because hot compound is tending to penetrate the single sheet of paper from both sides, and as the actual time of immersion is short, a higher temperature can be employed than in the post impregnation process. This, in turn, means that ample mobility at the impregnating temperature can be attained at the same time as complete solidity at atmospheric temperature, and high viscosity at the greatest working temperature of the cable. Moreover, its electrical properties do not have to be subjugated to physical considerations."

" Having thus practically a free hand from the physical point of view, the Glover process has an important initial advantage."

" Following the production of the perfectly impregnated dielectric material, it remains to assemble it in the necessary laminated form upon and around the conductors in such a manner that no ionisable matter is occluded in the ultimate mass. Assuming that air and gases are excluded from the material as a result of the method of preparation above referred to, the proposition that occlusion of air is preventable by assembly out of contact with air (e.g., under hot compound) leaves little scope for argument."

"In the method of assembly, the cable rotates on its own axis at a suitable rate while travelling laterally through a trough of compound, causing the strips of previously impregnated paper to be accurately wound upon it. It will be seen that the strips have to pass through an appreciable depth of compound before reaching the cable, and that the whole area of assembly is completely excluded from air, so that the only matter which can be entrained in the lappings is a thin film of the compound, the thickness of which is dependent on the viscosity of the compound at the trough temperature and the tension applied to the paper strips: and, as these conditions are closely constant, the film is correspondingly uniform throughout both the length and the radial thickness of the insulation. The actual thickness of the film is of capillary order but is sufficient to allow the necessary amount of movement of the papers over one another when the cable is bent."

"The rotation of the cable during its traverse entails revolving the payoff and hauloff drums and gearing, and the machine as a whole consists of two revolving carriages containing these respective parts, with an intervening section containing the cable trough, compound reservoirs, circulating pumps, and the stationary paper 'heads' mounted on longitudinal bars, and precision arrangements for controlling the tension, angle of application and staggering of the paper strips."

"These arrangements are, of course, an appreciable factor in the production of a solid uniform dielectric, because every paper strip bears its proper mathematical relationship to its angle of application for the diameter to which it is applied, and fulfils the requirements for laying flat, without wrinking or formation of pockets."

"The conditions are accurately set by schedule for any given job, as in machine shop practice, and are constant throughout the whole length of cable. As the heads are stationary, the closest supervision is rendered possible, whereas the rotating heads in ordinary lapping machines are only open to inspection when the machine is stopped. The only stoppages are for the purpose of renewing the discs of impregnated paper, breakages of strips do not occur. Renewal of exhausted lengths of strip does not entail exposure of the cable."

"The physical conditions in the dielectric proper resulting from the above described impregnating and assembly processes are as follows:

(1) In every part of the paper itself there is a uniform filling of compound which is solid at normal temperatures and highly viscous at the maximum working temperature of the cable.

(2) All interstitial spaces in the dielectric, i.e., between the layers of impregnated paper, and between the edges of their convolutions, are filled and sealed by the entrained compound which, being in the form of thin films, is to a large extent held in place by capillary forces, apart from the viscosity of the material."

"As a result of these conditions, it is ensured that:

(a) The electrical stability of the dielectric under high values of electric stress is a maximum, because of the elimination of ionisable matter.

(b) Under an infinity of heating and cooling cycles, representing working conditions, physical stability is maintained, i.e., no bleeding or draining of free compound can occur. (The direct connection between (a) and (b) will be referred to later.)"

"So much for the dielectric proper. There is yet another part of the cross section of the three core cables to be considered, viz., the padding or filling spaces."

"It is not, I think, well appreciated that such bleeding as occurs in a cable under the drainage test is almost entirely via the interstices of the stranded conductors—which constitute an absolutely free path—and the padding spaces."

"The ordinary paper string or compressed paper strips used to fill these spaces—in fact, any fibrous construction of padding—constitute a series of laterial tubes or channels, which, compared with the laminated dielectric, may also be regarded as fairly free paths, especially when the cable is vertical. These tubes or channels are difficult to drain when enclosed in the cable on the drum before lead sheathing, but will even, on the other hand, slowly drain the dielectric proper when installed in a vertical shaft under hot working conditions."

"In our cable, these drawbacks are obviated by filling the strand interstices with a plastic compound which cannot be liquefied by heat and, therefore, cannot flow from its original position. It is applied over each layer of wires during the stranding operations, and the succeeding layer strongly compresses it into the underlying layer, and also receives the surplus exuding outwards under the pressure of wires."

"The filling of the spaces between the insulated cores is accomplished by laying up four accurately preformed strips of resilient compound along with, and fitting—with a small margin of compressibility—the insulated cores. The centre quasi-starshaped strip fills the central interstices of the cable and embraces about 35 per cent. to 40 per cent. of the periphery of each insulated core. The other three strips of quasi-crescent form fill the outer spaces and butt hard against the projecting webs or star points of the centre strip."

"In line with the general principles of our method of manufacture, the assembly of cores and padding strips is performed under hot compound, and from the point of convergences of the component parts, the cable passes on to receive its overall lappings under the same air excluding conditions as the core insulation."

"Finally, the lead sheath is also applied under air free conditions, a special arrangement being attached to the lead press to ensure that the cable is immersed in and kept under a head of compound right up to the point where the lead sheath closes on to it. That is to say, there is a supply of compound fed to the cable, and the clearance annulus is filled: whereas, in the ordinary process, the tendency is for the impregnating compound to be drained out of the insulation by the heat of the lead press box, and the annulus to contain an appreciable amount of air and gas."

"Surveying the cross section of the cable up to the lead sheathed stage, we have :—

(a) Conductors with interstitian spaces filled with non-meltable compound.

(b) Core dielectrics free from ionisable gases and having all spaces between laminæ, etc., filled with films of compound, the conditions as a whole being such that physical (and, consequently, electrical) stability is ensured under all working conditions of the cable.

(c) Non-fibrous, resilient fillings which can neither themselves move in relation to, nor permit gradual drainage from, adjacent paper surfaces.

(d) Overall or belt insulation having the same properties and characteristics as the core dielectrics (b).

(e) The clearance space between the outer surface of the dielectric and the inner surface of the lead sheath completely filled with a film of viscous compound."

Each cable is made up of eleven individual lengths, the longest of which are in the vertical in No. 14 shaft, and consist of two lengths (for each cable system) of 1,150 feet each. The cables are supported in the vertical, at intervals not exceeding 45 feet, by oneway creosoted oak shaft cleats and brackets. These clamps were fixed in position in the shaft before lowering operations were commenced.

A skeleton cage was built on the mine to take the cable drums (which were specially made with cast-iron bushes), the latter being mounted on 6 in. cam shafts fixed to the cage on which they were free to rotate, but held in check by a screw brake.

This cable cage was lowered after the upper end of the cable had been clamped in the required position, two men operating the brake and paying out the cable. The winding rope was passed through another cage about 40 feet above ; the latter cage was operated by a separate winding engine, the rope for this purpose being temporarily diverted into the same compartment as the cable cage. The clamping was performed by two men in the upper cage, on which was a platform projecting towards the wall of the shaft to enable the men to reach the cable clamps.

The movements of the two winding engines were controlled by specially prearranged signals, and the work was carried out admirably, without any hitch. The cable drums containing the longest lengths of cable (1,150 feet) were approximately 11 feet in diameter and weighed about 11 tons.

The horizontal lengths of cable underground were supported at distances not exceeding four feet by clamps suspended from a catenary wire consisting of discarded hauling ropes fixed to the side walls and with tension bolts at suitable distances. The cable supports are attached to the catenary wire by easily breakable galvanised wire binders.

For the long stretch of cable along the 29th level haulage, the cables were paid off the drums on to mine cars, transported to the site, hauled up to the hanging by ropes and hung on to their supports.

During jointing operations, which occupied from 10 to 12 hours per joint, temperature and relative humidity figures were taken. The maximum figures obtained were 110°F. and 89 per cent. humidity. The average values for these figures were 80°F. and 82 per cent. relative humidity.

When the joint is completed, prior to pouring, the joint box lid is bolted on and a dessicator applied. The dessicator consists of a petrol engine driven air pump, which pumps air at a few pounds above atmospheric pressure through a series of four vessels containing a calcium chloride drier in trays, thence by a hose and connection to the sealed joint box, whence it exhausts to atmosphere by a pet-cock screwed into the box for the purpose. The period for dessicating was varied from half to one hour, according to the humidity.

As most of the joint boxes contain over 200 pounds of compound, and bearing in mind the extreme importance of avoiding, as far as possible, the occlusion of gases in the compound during filling operations, the compound boiler is equipped with a hand pump for circulating the compound during the heating period, and later, by the manipulation of valves, for the filling process, the compound being piped to the boxes. The compound is heated by a paraffin burner to about 10°F. higher than the pouring temperature of 320°F. ; the the break-down voltage of the compound is 55 k.v. for the B.E.S.A. oil testing gap, i.e., 150 mils between ½in. spheres.

For the inbye joints it was necessary to retain the boiler in the cage and pipe the compound through piping as long as 24 feet to the boxes, in which case it was necessary to heat the pipes with blow lamps before pouring.

After the joint boxes had been sealed up and allowed to cool off for a period of not less than seven days, they were opened up and topped : the shrinkage was found to vary between 1¾ins. to 3ins. In spite of these elaborate precautions, air holes showed up in one or two cases ; these were carefully heated with blow lamps and melted compound allowed to fill in, after which they were topped.

The installation was carried out in a well-organised and workmanlike manner by the mine staff, under the supervision of Mr. Winstanley, the contractor's cable engineer ; the jointing was also done under the supervision of this gentleman by the contractor's jointer ; it was one of the conditions of the contract that the mine cable jointers should be initiated into all the phases of supertension jointing, which was duly carried out, there being one or two of the mine men present and helping at all jointing operations.

(*To be continued.*)

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LONDON BRANCH.

Voltage Regulation as Applied to Transformers

A. C. WHISH and J. N. ROBERTSON.

(*Paper read 17th April*, 1929).

On large networks it is necessary to have voltage control equipment not only to ensure a constant voltage supply at the consumers' terminals, but to give complete control of the load on that network. It has been found convenient in many cases to have this voltage control at the transformers, and various methods have been adopted. Regulation may also be obtained by means of an induction regulator, which, while it does not truly come under the title of this paper, has been included on account of the important position it holds in voltage control.

The network cannot be maintained at a constant voltage at all points, owing to the nature and variations of the load, and different methods are required to deal with the different conditions which arise.

Generally these conditions may be summarised as follows:—

(1) Where the load may be disconnected and few changes are necessary.
(2) Where the load may be disconnected but more frequent changes are necessary, which must be made rapidly or with a minimum of inconvenience.
(3) Where the load cannot be disconnected.

The first case will generally include all distribution transformers where the secondary voltage is to be maintained constant. Two conditions have to be met: firstly, the natural and seasonal growth of load on the distributors; and secondly, the variation of the primary voltage which will vary relatively to the distance of the transformer from the feeding point. Tappings on the transformer winding to give a variation of + and — $2\frac{1}{2}$% and 5% will generally meet the above requirements, but wider ranges are frequently called for.

These tappings are usually fitted on the higher tension windings, as with the larger total number of turns it is possible more nearly to obtain the required percentage. It may be observed that from this aspect it would be frequently impossible economically to provide tappings on the L.T. windings at the required value. Further, the current in the higher tension windings is very much less, making it an easier manufacturing problem to bring out the necessary leads.

The tapping leads are brought up to a terminal board immediately under the oil level. To make the voltage change the transformer is disconnected and a link or jumper moved to the required tapping. This method has certain disadvantages, such as the considerable time which may be taken to carry out the operation, the possibility of making a wrong connection, and the liability of some foreign substance being inadvertently dropped into the tank. It is, however, the cheapest method and widely adopted.

In order to avoid the inconvenience of the above method, and with the introduction of transformers fitted with conservators and outdoor transformers, it became necessary for some other means to be employed. For instance, clearly it would be impossible to open up a conservator transformer each time a tapping change was to be made, or to be dependent on the weather. Again, in power transmission the change of tappings may be more frequently required and must be made expeditiously. To meet these conditions a hand operated switch is employed to replace the terminal board. The switch may be fitted on the top of the transformer yoke or in the case of core type units about the middle and in front of the windings. The latter position is advantageous in that it keeps the length of the tapping leads a minimum, but it may increase the size of tank and oil quantity considerably.

The switches are mechanically coupled to an operating handle or handles which are fitted either under a hand hole cover in the lid or externally. The latter arrangement is, of course, essential in the case of transformers fitted with conservators and desirable for outdoor transformers.

An indicator is always fitted to show the tapping in use.

This arrangement allows of a quick change to be made and also guards against a loose or wrong connection.

With the introduction of very large units and the interconnection of large systems, it has been necessary to develop a means of altering the voltage ratio without interrupting the circuit. There are two methods by which this may be done, each of which has its advantages and disadvantages:—

A—Induction Regulator.
B—(i) Booster Regulator.
(ii) Transformer Tap Changing under load.

(A)—*Induction Regulator.*

The construction of an Induction Regulator is generally similar to that of an Induction Motor, but the rotor is kept stationary in a position which can be adjusted by suitable mechanism operated by hand or power.

The primary or exciting winding is connected across the supply circuit with the secondary or series winding connected in series with the circuit to be controlled. It is immaterial which winding is on the stator and which on the rotor, but it is usual to have the secondary on

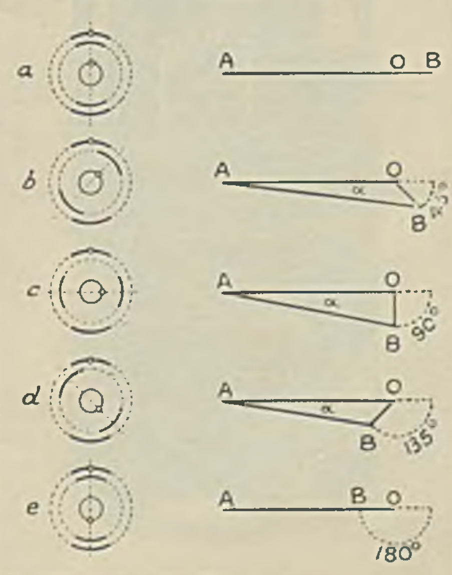


Fig. 1.

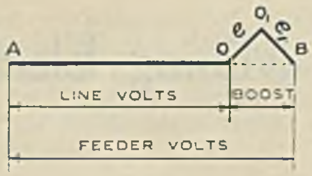


Fig. 2.

the stator, as this is the heavier current circuit and can be more rigidly fixed.

In the three phase regulator the primary winding generates a rotating field as in the case of an induction motor, therefore the magnitude of the voltage induced in the secondary winding is unaffected by altering the position of the rotor. Movement of the rotor does, however, vary the phase relation of the induced voltage to the primary voltage, and hence the vector sum of the supply voltage and regulator secondary voltage also varies and the desired regulation is obtained.

This is illustrated in Fig. 1, where A O represents the line voltage applied, O B the secondary voltage of the regulator, and A B the resultant regulated feeder voltage. In the extreme rotor positions "a" and "e" the secondary voltage is respectively in phase with and in opposition to the line voltage, and the resultant voltage A B then has its maximum and minimum values. For intermediate positions of the rotor the secondary voltage is out of phase with the line voltage as shown in "b," "c," and "d," and consequently the resultant voltage has a phase displacement relative to the supply.

On a dead end feeder this is of no consequence, but on a ring main system, or where the low voltage sides of transformers on two feeders are interconnected, this phase displacement may cause heavy wattless currents to circulate.

To avoid this defect it is necessary to adopt a twin three-phase regulator. This regulator consists of duplicate three-phase regulators, simultaneously operated, each of half the required K.V.A., and with their secondary windings connected in series in such a manner that the phase shift of one is neutralised by the phase shift of the other. This is shown diagrammatically in Fig. 2, where AO is again the line voltage and AB the regulated voltage. OO_1 and O_1B are the secondary voltages of the two halves of the twin regulator. A O and A B are now in phase for all positions of the regulator.

An alternative means of overcoming phase shift is the use of three single phase regulators where the secondary voltage is proportional to the alternating flux which threads the winding, and is therefore reduced from maximum to zero, as the rotor is turned from full boost position to neutral. If the movement is continued, the direction of the flux relative to the secondary winding changes and the phase of the secondary voltage is reversed. A complete angular movement of the rotor through one pole pitch will, therefore, give full positive and negative range of regulation without any phase shift. When the rotor is in the neutral position, the secondary and primary windings are not mutually inductive and the secondary would act as a choke tending to saturate the cores. To avoid this an auxiliary short circuited winding is provided on the primary and arranged electrically at right angles to the main primary winding. This additional winding, if properly proportioned, does not increase the losses in the regulator. A bank of single phase regulators is, however, more costly and less efficient than a three-phase regulator and their use is not general.

A typical regulator is shown in Fig. 3.

The feature of the Induction Regulator is the smooth voltage regulation and absence of switchgear.

The rotor, however, is subject to vibration set up by the alternating field, and great care has to be given to the design in order to minimise noise and to avoid deterioration of the insulation from this cause.

B—(i) *Booster Regulator, and* (ii) *Tap Changing.*

The "booster regulator" and "on load tap changing" are fundamentally similar in that they both depend upon switchgear suitable for transferring the load

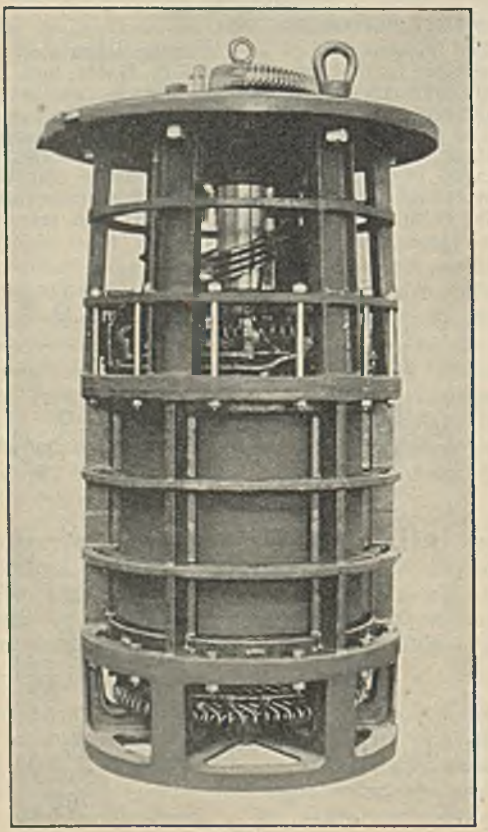


Fig. 3.

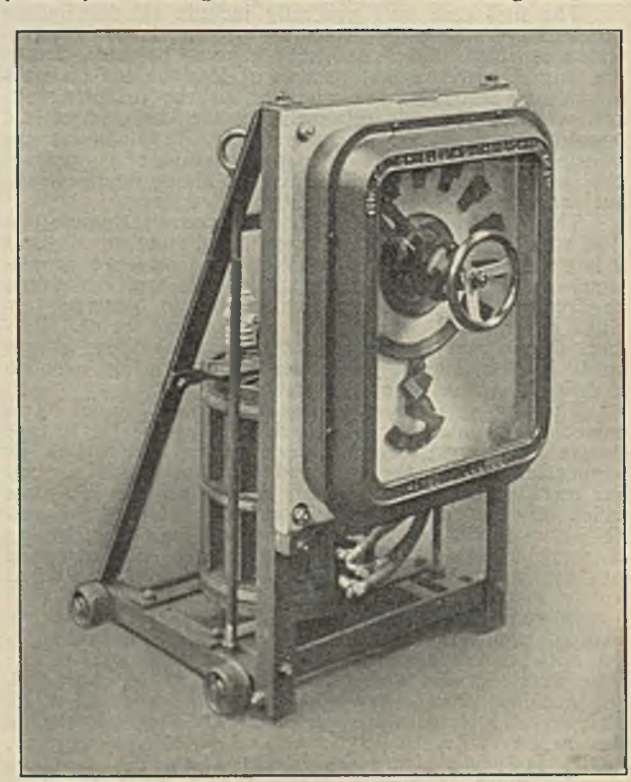


Fig. 4.

from one transformer tapping to another without interrupting the circuit, and it is therefore important to note that by common usage "on load tap changing" is used to refer to voltage regulating means utilising tappings provided on a main double wound transformer.

The former, which was the first system developed, involves in its original form a simpler switchgear problem, as it will be seen from the descriptions which follow that the switching was done in a low voltage circuit or in an isolated circuit the voltage of which is but a fraction of that of the circuit being controlled. Further, the switchgear is entirely separate to the transformers (although in small sizes it may be fixed to it for convenience) as the interconnections to the switch do not present any difficulty with the comparatively low voltages employed, and the switchgear designer has had practically a free hand.

In the case of "on load tap changing" the switchgear becomes essentially part of the transformer and preferably is assembled on to the transformer tank in order to avoid the necessity of bringing out of the tank a considerable number of high voltage leads from the windings, which would often be almost impossible and in all cases very expensive. It is, therefore, necessary to have available switchgear which is suitable for working in the main circuit and of a design convenient for assembly as part of the transformer. When it is remembered that on large high voltage transformers practically the whole of the available tank surface can generally be effectively utilised for the various accessory fittings such as cooling radiators, explosion vents, bushings, inspection doors, etc., it will be realised that the designers of these gears have had as one of their aims to provide the most compact arrangement possible—and high voltage and compactness not easily consorting, considerable ingenuity has been required. Even so, the minimum physical dimensions and cost are such that this method of voltage regulation cannot be economically applied to transformers below a fairly large size.

The advantages and disadvantages of the two systems at the present time may be briefly summarised as follows, although it is the author's view that the design of "on load tap changing" gear will rapidly evolve and become more generally applicable than it is at present.

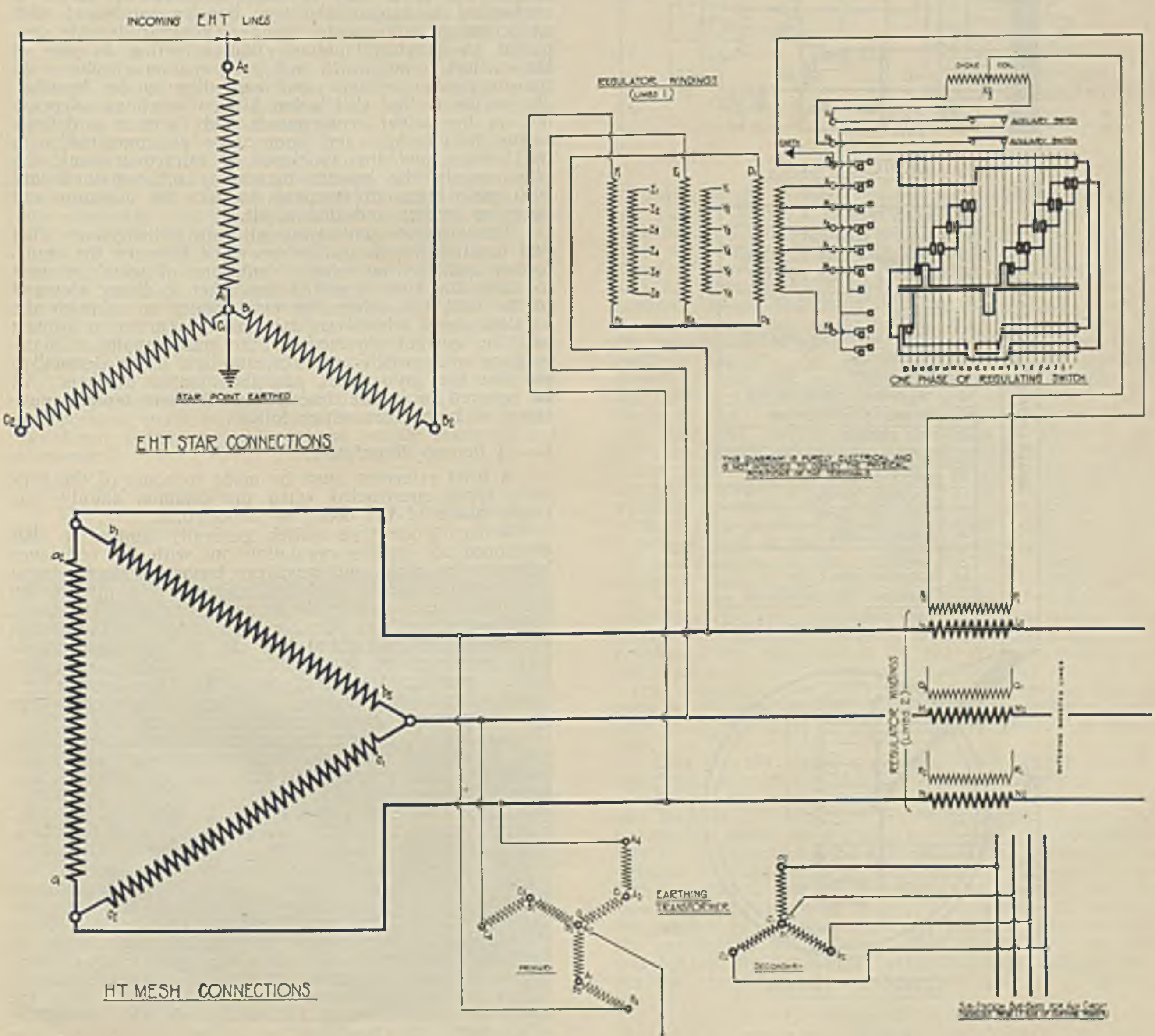


Fig. 5.

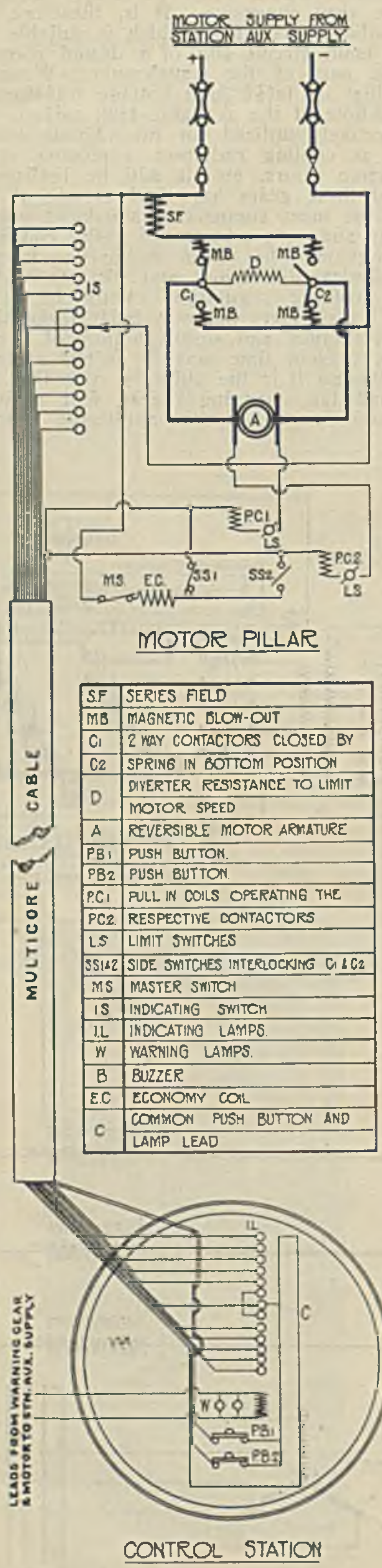


Fig. 5a.

Booster.

Entirely separate from the transformer and therefore applicable at any point in a circuit.

Main transformers remain as simple as possible, no tappings being necessary, and therefore have maximum reliability.

Considerable floor space required for booster gear alone.

More expensive and less efficient.

On Load Tap Changing.

Can only be applied at a main transforming station.

Main transformer complicated by additional taps and auxiliary apparatus and possibility of trouble is therefore increased.

Floor space of main transformer very slightly increased, if at all.

Cheaper and more efficient.

It is of interest to note that with the development of high voltage switchgear for direct connection to a transformer it is now possible where size makes it economical to replace the true booster equipment with an equivalent auto-booster using switchgear directly connected to suitable tappings, thus reverting to one of the earliest forms which had become unpracticable with the increasing voltages and capacities to be handled. The saving in first cost is but little, if anything—depending on the actual requirements—but there is a definite saving in efficiency and floor space as compared with the booster and the avoidance of interconnections; in other words, the booster becomes a self-contained unit with cable boxes or terminals to take the incoming and outgoing feeders and that is all.

The principle underlying all this switchgear is that two parallel circuits can be provided between the transformer and the out-going circuit, one of which is used to carry the current whilst the other is being changed to the next tap—when this new connection is made the parallel circuit which was carrying the current is broken and the current *diverted* to the new tapping. Many winding and switch arrangements have been devised to put this idea into effect, and the number of them will be referred to in the descriptions of some typical regulators of both types which follow.

B—(*i*) *Booster Regulators.*

A brief reference must be made to some of the very early types constructed when the common supply was single phase of the order of 2,000 volts.

A face plate type switch generally similar to that developed for battery regulation but with the resistance between the main and auxiliary bushes replaced by a choker or a separately mounted resistance was fitted to an auto-transformer having the necessary tappings (Fig. 4).

Generally it was possible to arrange for the switch to operate in the earthed line and its insulation, therefore, presented no great difficulty. Suitable renewable carbon sparking tips were provided on the brushes.

A considerable number of these simple units are still in use and giving complete satisfaction.

For higher voltages and larger sizes it became necessary to adopt a more elaborate arrangement, and Fig. 5 (with Fig. 5a) shows a typical case for a three-phase high voltage system.

Three "teaser" coils marked D_1—D_0, E_1—E_0, F_1—F_0 are connected in star across the three-phase lines. These coils induce a secondary voltage in coils X_1—X_0, Y_1—Y_0, Z_1—Z_0, which are provided with intermediate tappings. The tappings are connected to a three-phase regulating and reversing switch and by its means impress "bucking" or "boosting" voltages on coils P_1—P_0, Q_1—Q_0, R_1—R_0. These coils act as primaries to the boosting windings L_1—L_0, M_1—M_0, and N_1—N_0, which are in the main out-going circuits to be controlled.

A fundamental feature of the scheme is that the switching is done in an isolated circuit, the voltage of which need only be a fraction of the line voltage, thus simplifying the switchgear problem.

The capacity of the switchgear is dependent on the feeder K.V.A. and the amount of regulation required.

The face plate switch has main and pilot brushes, and six contacts are fitted. A choke coil or resistance is provided between the main and the pilot brushes to carry the current while the main brush is passing between contacts.

A change-over switch to reverse the connections between P_1—P_0 and X_1—X_0 is fitted and is automatically operated by the movement of the regulating switch as it passes through the position of "no boost."

Two contactors operated by cams on the main shaft are in series with the main and pilot brushes respectively so as to break the circuit before the corresponding brush of the regulating switch leaves its contact and to make it again after the brush has moved on to the next contact. The switch is therefore not called on to break the circuit, and no sparking or burning of the contacts takes place.

A drum switch has now been designed to carry out the same function, and this type can be built for heavier service.

The regulating switches of both types are adapted for operation by hand, remote, or automatic control.

For the latter two cases a motor operating pillar is coupled to the switch spindle. The principle of this is to raise a weight by means of a motor, which, when released, operates the switchgear thus relieving the auxiliary supply from the responsibility of completing the operation once it has commenced.

The control of the motor is by means of two buttons, one to "raise" and the other to "lower." Indication is given on the control point of the position of the regulator by means of a series of lamps behind suitably numbered opal glass plates and controlled by means of a multiple switch in the motor operating gear. An alarm is fitted in the control panel which will give warning should the switch stop in a mid-way position between contacts. Automatic operation is obtained by the addition of a suitable voltage relay in place of the push button. Fig. 6 illustrates a booster equipment.

The advantages of the booster regulator are: When working with a main transformer it is easy to arrange so that the regulator can be readily cut out and the main transformer operated at a fixed ratio; there are no working parts in the main transformer tank; the switchgear being accessible can be readily inspected and overhauled.

B—(ii) *Tap Changing.*

The various schemes for "on load tap changing" may be grouped under perhaps four main headings

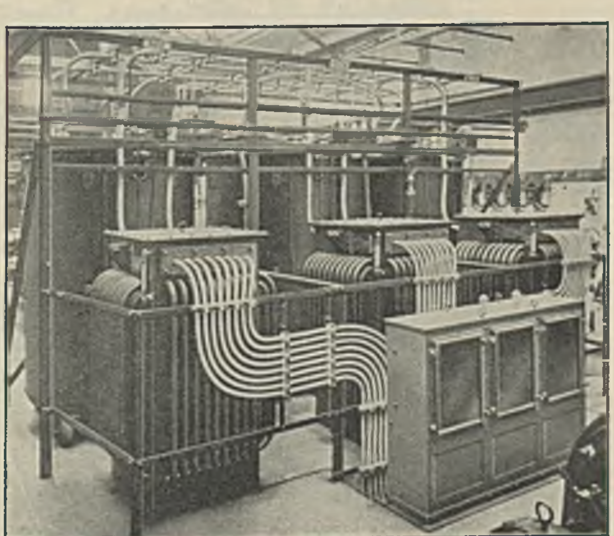


Fig. 6.

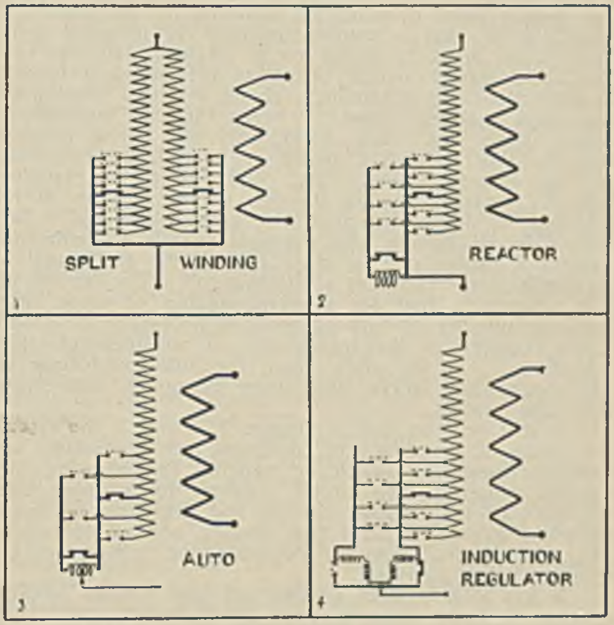


Fig. 7.

according to the method adopted for providing the parallel circuit during a change: (1) Split winding; (2) Reactor; (3) Auto-transformer; (4) Induction Regulator; and these are typically illustrated in their simple forms to a single phase winding in Fig. 7, diagrams 1, 2, 3 and 4, although it must be remembered that modifications can be and are introduced for various reasons.

In (1), as the name implies, the main winding of the transformer is split into two parallel portions each similarly tapped, the ends being connected together directly at one end and through two circuit breakers at the other. These two windings are so disposed relatively to one another that the reactance between them will limit the current which circulates in them to an allowable figure when the tapping switches are on different taps. The tapping change is made by opening one of the circuit breakers, changing the tapping on that winding, re-closing the adjacent circuit breaker and then performing a similar operation on the other winding. It will be seen in the intermediate change position when one winding is on one tapping and the other on an adjacent tapping, that there is a current circulating in the windings during the few moments when both circuit breakers are closed, which makes necessary the specific inter-reactance referred to in the preceding paragraph—further that during the change each winding is called upon in turn to carry the total load current for a few moments. For both these reasons the method is open to criticism although a number of transformers have been built with gear utilising this arrangement of windings.

Diagram (2) shows a scheme which is not open to the criticism applying to (1). A single winding is provided and the tappings are alternatively connected to two busbars by means of circuit breakers. Across the bus-bars is connected a plain reactor or choke coil which may be short circuited by a further circuit breaker. The running position is with one of the tapping circuit breakers closed, and the reactor short circuited, and to change to the next tapping it is necessary to unshort the reactor by opening its circuit breaker, then to close the breaker to the adjacent tapping and open the circuit breaker to the tapping recently in use, finally closing the reactor circuit breaker thus again short circuiting it.

Group 3 is very similar to Group 2 and the sequence of switch operation is also somewhat similar. The choking coil is, however, replaced by an auto-transformer the middle point of which is connected to the load, and it differs in that a running position is obtained with two circuit breakers closed on to adjacent tappings and the short circuit switch opens as the auto-transformer is then across these tappings, giving a virtual tapping on the main winding midway between the two tappings in use. If, on the other hand, only one circuit breaker and the short circuiting switch are closed, the two ends of the auto-transformer are connected to one tapping and the currents flowing through the two halves of its winding to the centre neutralise each other, and it becomes to all intents and purposes merely a conductor. During a change one or other half of the auto-transformer acts momentarily as a choking coil. The feature of this scheme is that for a given number of steps only half the number of tapping sections necessary in Group 2 are required in the transformer—a not inconsiderable advantage. On the other hand, the auto-transformer is an appreciably larger and more expensive item than the plain reactor.

It will be seen that in Groups 1, 2 and 3, the essential items of the complete equipment are a reactance or auto-transformer, a switch or switches for selecting the tapping required, two circuit breakers for opening one or other of the parallel circuits and diverting the load current into one of these two circuits, and an operating and timing mechanism to correlate the movements of these switches correctly.

It has already been pointed out that various modifications of these schemes have been devised, and this has been done mainly for the purpose of cheapening and simplifying the necessary switchgear, as for instance in Group 2 it is easy to see (Fig. 8) that if two circuit breakers are introduced between the ends of the choking coil and the bus-bars, and the choke doubled and the middle point taken to the load; the multiple circuit breakers shown in the diagram may be replaced by two simpler switches which are only used to select a tapping and are not required to break the circuit.

In the running position when both tap switches are on the same tap and both circuit breakers are closed the current flows in opposite directions through the two halves of the choking coil thus neutralising each other and avoiding the necessity for the short circuiting switch shown in (2).

With system 4 an induction regulator replaces the reactance or auto-transformer, and by means of it the potential of the outgoing lead is smoothly changed from that of the tapping to which it is connected to the potential of the adjacent tapping, when it is then connected directly to it and the circuit to the old tapping opened.

The regulator is in effect an auto-transformer of infinitely variable ratio and the operation may be easily understood by reference to diagram 3, imagining that the midpoint tapping on the auto-transformer there shown is movable and can be moved along the winding from one end to the other. Suppose that this tapping is at, say,

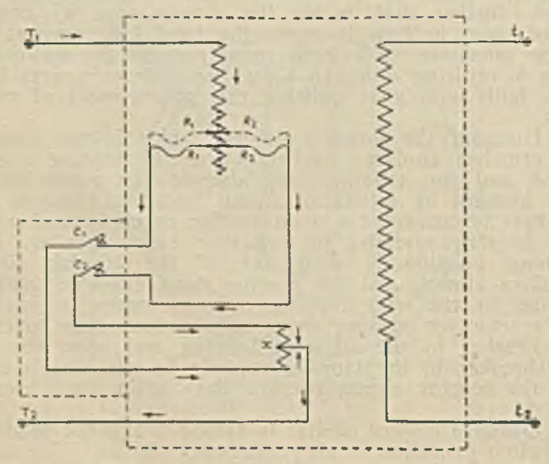


Fig. 8.

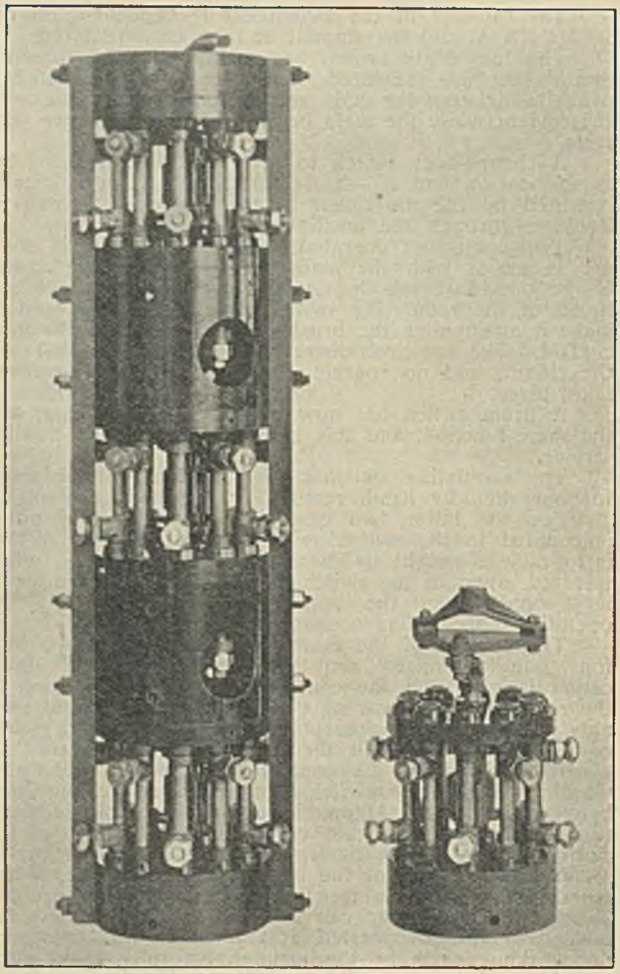


Fig. 9.

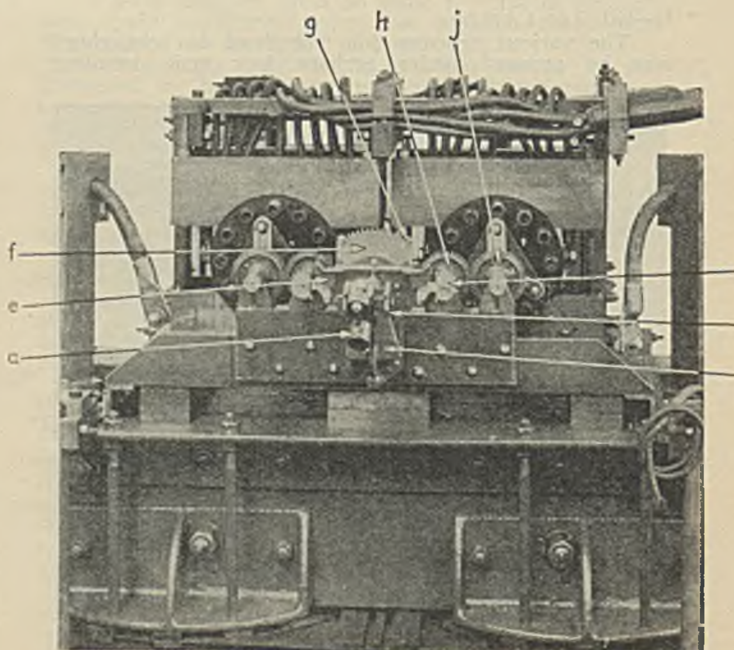


Fig. 10.

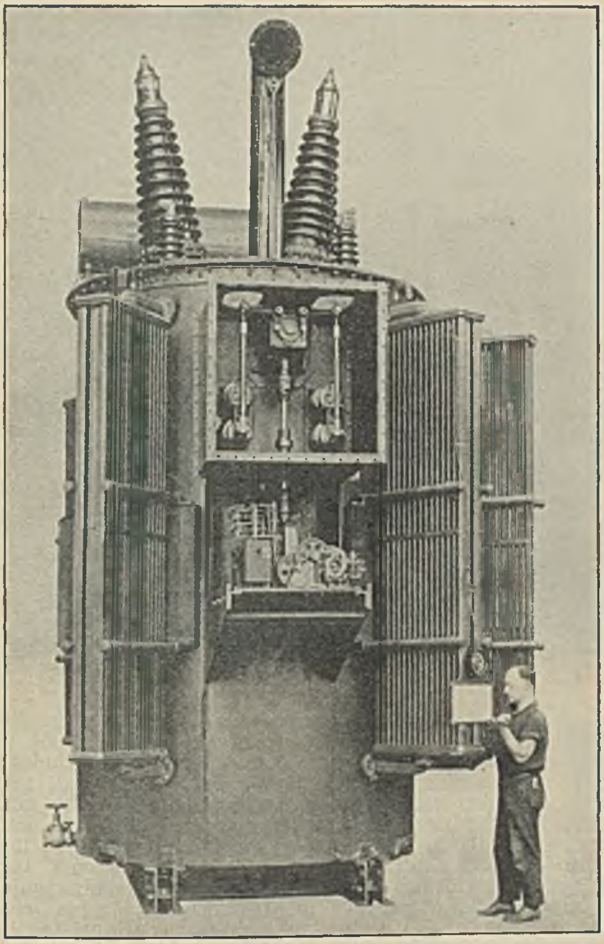


Fig. 11.

the left hand end of the winding, that the short circuiting switch is omitted altogether and that the switch connected to the right hand end is open, then the outgoing lead is clearly connected directly to one of the transformer tappings; if now the right hand switch is closed the tapping can be moved along the auto-transformer winding until it is at the other end when the outgoing lead will have been gradually transferred to the next tapping and the first or left hand switch can be opened to break *only* the magnetising current of the auto-transformer. The especial characteristics of the system are, therefore, the smooth regulation of the voltage and the light duty for the switchgear.

A further feature is that it is possible, if the regulator is constructed for continuous rating, to provide an infinite voltage variation between the two limits. It must be remembered, however, that this would considerably increase the cost and size of the regulator.

Before leaving the subject in general terms attention must be drawn to the relation of the size of the choking coil, or its substitute, and the duty of the switches to the size of the voltage step. It is clear that the choking coil or its substitute has to carry a current which is a definite function of the main winding current and also that it has to operate across the voltage between adjacent transformer taps; its actual size, therefore, is directly proportional to the intertap voltages—in other words, if regulation is required in 2% steps the choking coil or its equivalent will be twice the size required if regulation is given in 1% steps. It has already been pointed out that in system 4 the switchgear is only called upon to break the magnetising current of the regulator, whereas in the other systems it has to break the K.V.A. capacity of the choking coil at least and in certain circumstances appreciably more. Assuming, however, that in adverse conditions it is called upon to break about double this K.V.A. on a 40,000 K.V.A. transformer with 2% steps the switches normally will only have to deal with about 500 or 600 K.V.A., which a well designed switch can handle many times without overhaul or adjustment, and their duty will be proportionately reduced in the case of smaller units and smaller steps.

It is only possible in a paper such as this to give a brief description of a few actual equipments but before doing so it may be noted that in putting these schemes into practice it is an accepted principle that any switch which breaks current must be outside the main transformer tank and reasonably accessible, whereas those which are only moved when disconnected from the load may be located inside the tank. The latter in all cases are the switches used to select the appropriate tapping while the former are used to open one or other of the parallel circuits. They may, therefore, be very conveniently designated selector switches and diverter switches respectively, and these terms will be used in the descriptions wherever they are appropriate.

The first equipment illustrated follows diagram 2 modified as already referred to (Fig. 7). The taps in the main winding are connected to selector switches indicated at R_1 and R_2 in Fig. 8. They are fitted in the main tank in the most convenient position for the connections required and two are employed each normally connected to the same tapping. The operation consists of turning first one and then the other to a new position by means of an intermittent gear. Before either of these switches is moved, however, the related circuit if opened by one of the diverter switches C_1 and C_2 which actually take the form of oil immersed contactors (Fig. 9). During the period of tap changing when the selector switches are on different tappings and both diverter switches are closed, the circulating current is limited by the reactor X, which is usually housed in the main transformer tank.

Fig. 10 shows both a single and three-phase switch, the contact fingers "b" are withdrawn from the cylindrical contact bars by an eccentric marked "a" and

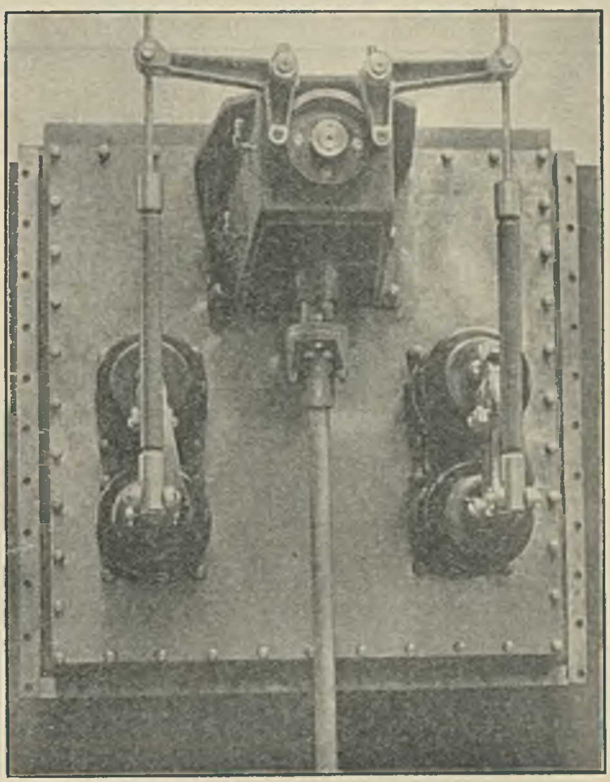


Fig. 12.

rotated to the next position opposite the appropriate contact bar when they are forced forward on to it with a wiping action.

The intermittent gear is designed to move each selector switch or group of selector switches alternatively. The gear locks the switches in their correct positions and also each switch during the operation of the other. Fig. 11 shows a single phase transformer fitted with this gear.

The movement of the selector and diverter switches is effected at the appropriate times by a separate motor driven mechanism usually fixed over or under the diverter switch casing. This casing also contains the motor starting contactors for either direction operated from the control station by a push button—a position indicator switch—and a switch to give an alarm should the movement not be completed.

The next equipment uses an auto-transformer (Fig. 12), the tappings being provided in the usual manner at about the middle of the H.T. winding. On each phase the tappings are connected to the contacts of a selector switch which comprises in effect two common bars which can be respectively connected to the contacts by means of one of the two parallel brushes. These brushes, which are insulated from each other and both mounted on the moving portion of the switch, are so spaced that they can both bear on the same contact or, alternatively, connect adjacent contacts, one to one common bar, and the other to the second common bar. Further, the dimensions and spacing of the contacts and brushes is such that as the latter are moved along the switch, the leading brush reaches the second contact while the other brush is still on the first contact, and also that the insulation between the contacts is maintained as the leading brush passes from one to the other.

The two common bars are connected each through a diverter switch to either end of an auto-transformer, the middle point of which is connected to the second portion of the main transformer winding.

The operation is indicated in Fig. 13, the diagram (i) showing the running position. In changing to the position (ii) the right-hand diverter switch is first opened and the brushes are then moved to the position shown which is half-way through one step. At this stage the load is carried by way of one brush and one half of the auto-transformer acting momentarily as a choking coil. (iii) shows the step having been completed, that is to say, the leading brush has moved on to the next contact, and a moment later the diverter switch has been closed and the second running position reached. In this position the auto-transformer is connected across two adjacent transformer tappings and a virtual tapping point is given mid-way between the two actual tappings from the windings. (iv) shows the mid-way position to the next step, to reach which the left hand diverter switch has been opened and the selector switch has moved until the trailing brush has reached a position mid-way between the two contacts. This again is a transitional position with the other half of the auto-transformer acting as a choking coil and the final position for the next step is shown in (v), where the two brushes are again bearing on one contact and both diverter switches are closed.

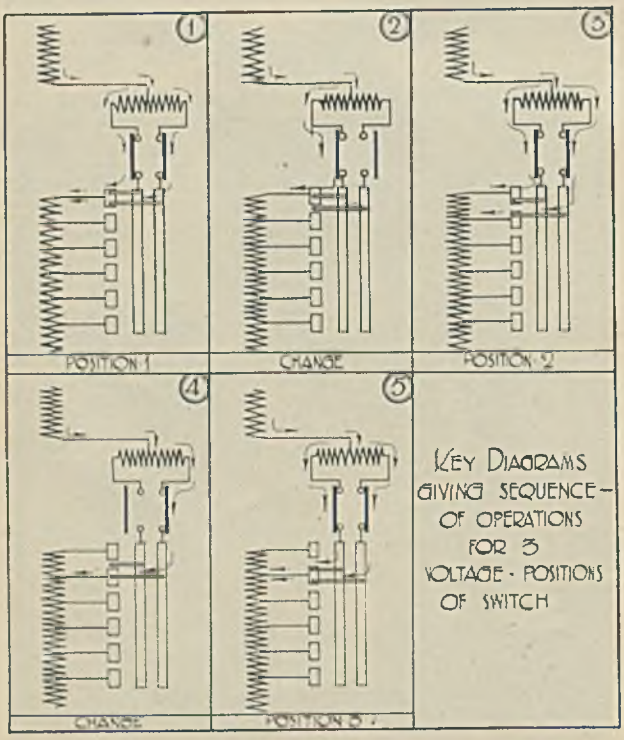


Fig. 13.

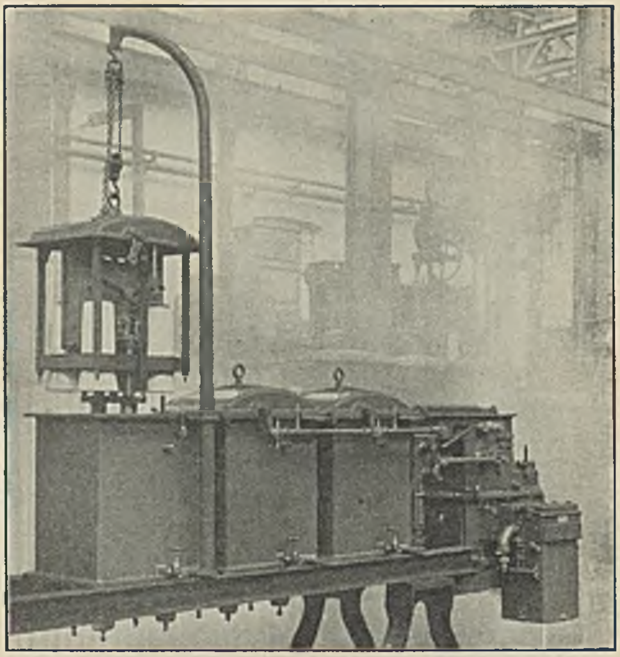


Fig. 14.

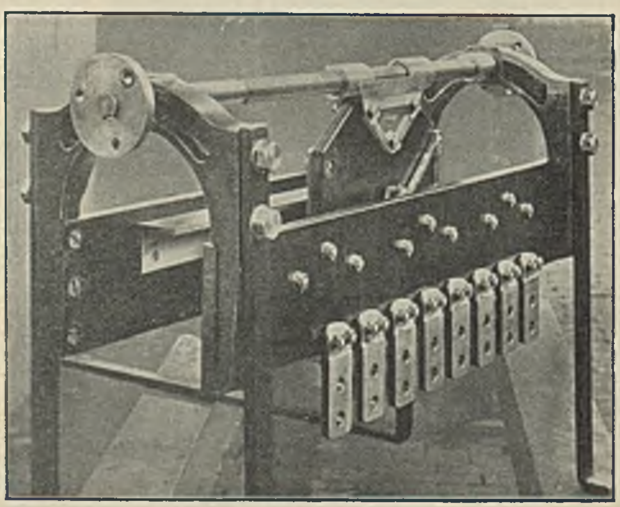


Fig. 15.

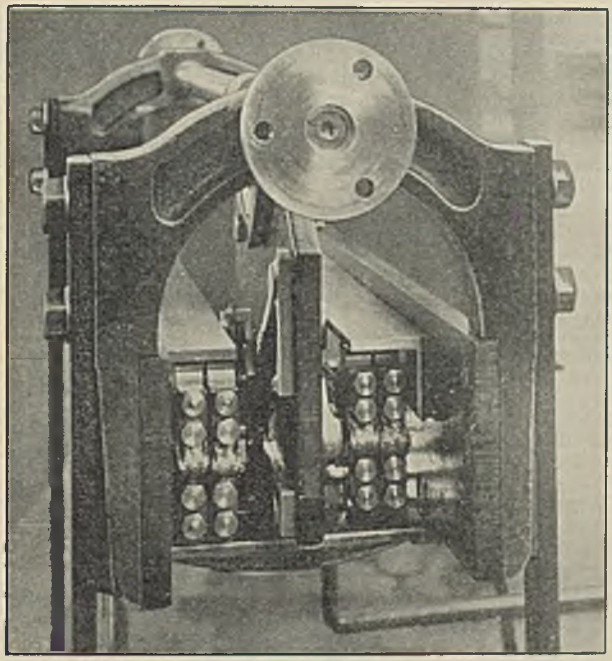


Fig. 16.

The equipment per three-phase transformer consists of six diverter switches (Fig. 14), two per phase, each pair contained in one tank, but independent from each other and with individual outside operating levers. The contacts are mechanically coupled together in two groups of three by means of adjustable connecting rods. The operation of these switches is effected through two tripping mechanisms which are mounted on the switch tank nearest to the step-by-step operating gear. The tripping mechanisms are provided with electrical interlocks which complete an alarm circuit as soon as a group of switches opens, and interrupt this alarm circuit again as soon as the group of switches has been closed. The whole of the working parts of each unit is bolted to the lid of

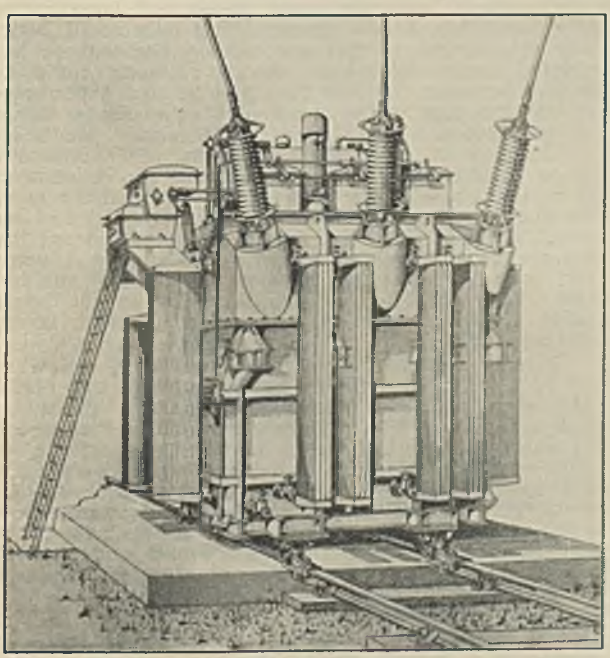


Fig. 17.

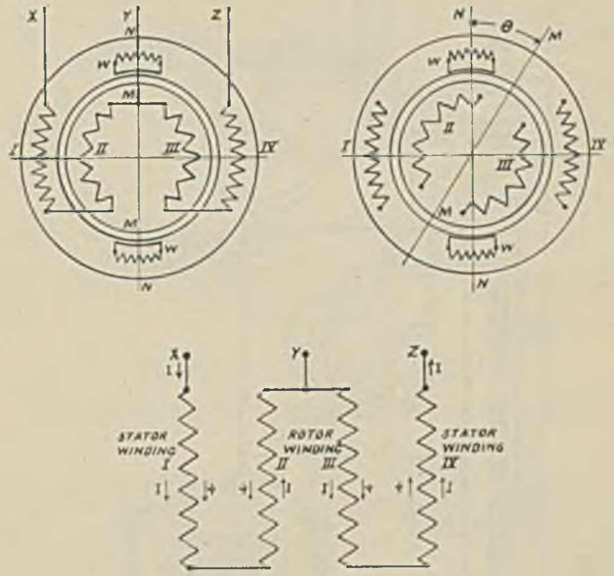


Fig. 18.

the switch tank and can be easily withdrawn from and lifted out of the tank for inspection, by means of a small interchangeable jib provided for the purpose, the connections from the switch contacts to the interior of the transformer being made through leading-in bushing insulators by means of self-aligning draw-out type plugs and sockets.

The opening and closing of the oil switches in the correct sequence is effected by a motor-operated step-by-step mechanism. A motor and a magnet operated brake are mounted inside a cast iron ventilated case provided with removable inspection doors. The motor and the brake are controlled by two triple-pole, reversing contactors which are oil immersed in a removable tank bolted to the outside of the cast iron case containing the former. The correct timing is obtained by interrupted spur gearing.

Hand operation can be obtained by means of a dog clutch actuated by an external operating lever which disconnects the motor and connects the hand wheel shaft to the mechanism.

The selector switches are illustrated in Figs. 15 and 16, and are mounted inside the transformer tank.

Fig. 17 is a perspective drawing of a 15,000 K.V.A. transformer now under construction for the C.E.B. showing the complete unit.

Lastly, the equipment employing an induction regulator has the taps of the main winding connected to oil immersed drum type switches which are fitted on the side of the tank, the connections being taken to them through porcelain bushes and the phases coupled by insulated couplings. These drums also carry the switches short circuiting the regulator in the running position.

The regulator has four windings (Fig. 18), two on the stator and two on the rotor. These windings are connected end to end so that the two windings on the stator are in true series while those on the rotor are in opposition to each other. If, therefore, the rotor is in such a position that maximum flux is threading both rotor coils one rotor coil is adding to the stator coils whilst the other is subtracting, resulting in Y being at the same potential as say X. If now the rotor is rotated through 180 electrical degrees Y will be at the potential of Z. During the rotation the potential of Y will vary smoothly between these limits. In order to limit the impedance of the windings during the rotation a short circuited winding W is provided on the stator in quadrature with the main windings.

A typical general arrangement is shown in Fig. 19. As before movement of the drum type switch and regula-

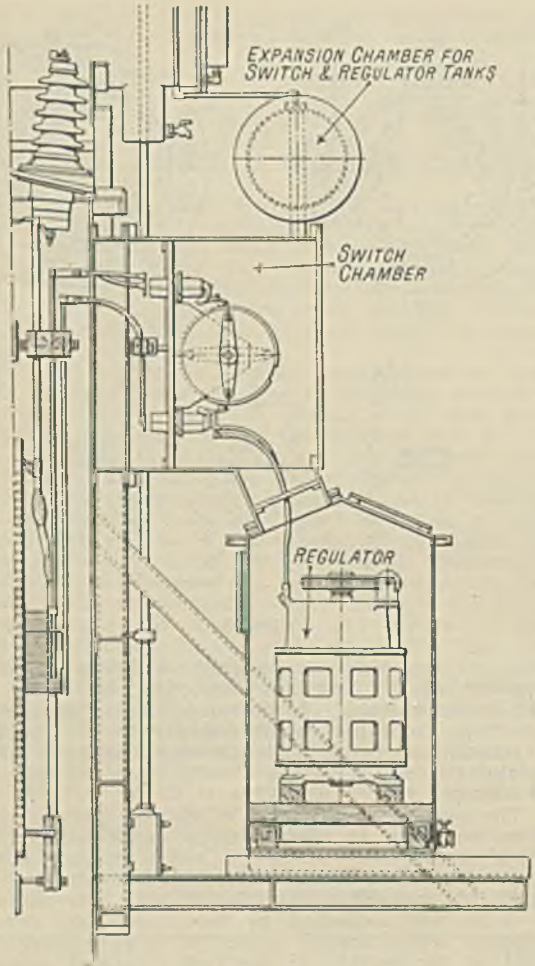


Fig. 19.

tor is effected at the appropriate times by a separate motor driven mechanism.

This, and the previous equipment described may be hand, remote or automatic controlled, and provision can be made to ensure that if two or more transformers are installed at one site control of any or all of the units can be made from a master switch which will ensure that they are brought into and retained in step while working in parallel.

In conclusion the authors desire to express their thanks to Messrs. The British Electric Transformer Co., Ltd., their work with whom has greatly assisted them in the preparation of this paper, and to The British Thomson-Houston Co., Ltd., The English Electric Co., Ltd., The Hackbridge Electric Construction Co., Ltd., and The Metropolitan-Vickers Electrical Co., Ltd., for descriptions and illustrations of their apparatus.

Discussion.

Mr. ALLEN WEST said that although the apparatus described in the paper was intended for the regulation of large units, and was no doubt expensive, the paper was of interest to colliery electrical engineers because in due course there would be a beginning of the development of apparatus for the regulation of comparatively small units. He expressed gratitude to the authors for their clear comparison of the different methods.

Mr. J. A. B. HORSLEY (Past Branch President) pointed out that the problem of voltage adjustment or regulation was interesting a number of collieries at the present time, certainly in cases of large amalgamations which had resulted in several colliery power stations feeding into a common trunk. The paper was one which it was necessary to study at leisure in order that one might absorb fully the information contained in it, but he had obtained the impression that by means of one or other of the devices mentioned it was possible satisfactorily to control the pressure both in the case of tail end feeders and in the case of a ring main, fed from one or more sources. He asked if the authors would confirm that.

Mr. C. DAWSON said his personal experience was that in transformers for colliery work which were supplied with plus and minus tappings for voltage regulation, the tappings were very rarely used. For instance, one might have a transformer fed through a shaft feeder arranged for supplying both motors and lighting; part of the day it would be loaded pretty well to capacity, but at the end of the day's shift the bulk of the power load would be taken off and it would be left to carry merely the lighting load. If one altered the tappings to give the normal line voltage to meet the heavy loading of the transformer, when the load was taken off the voltage was out of all proportion to what it should be.

Mr. D. KINGSBURY (Assist. Hon. Secretary of the Branch) congratulated the authors upon having tapped such a large number of sources of information; a fact which indicated the very happy relations existing between many manufacturers. Many engineers would be interested to know specifically what percentage of voltage variation was allowable. It seemed to him that change in the voltage of any particular transformer on any complex network would be accompanied by wattless current. One either made a change to limit wattless current or ran into a certain amount of wattless current in making a change, and it would be interesting to know the extent to which the voltage might safely be varied up and down. He had seen comparatively large regulating equipment in service, and undoubtedly as between two comparatively large systems an appalling amount of current could be produced which was doing no useful work.

Mr. J. R. COWIE (Hon. Secretary of the Branch) indicated one or two matters which the authors might with advantage have emphasised. For instance, in regard to parallel running it was mentioned briefly that in certain forms there might be phase displacement, which might result in either non-parallel running or, as mentioned by Mr. Kingsbury, bad parallel running. Again, in regard to tapping change, when some of the older methods were employed there had been rather bitter complaints from consumers that they could notice every tapping change that was made. The authors had indicated means by which smooth changing could be effected, however. A few days ago he had experienced the problem that certain auxiliaries in a power station had not enough voltage range. The minute one began tap changing in an upward direction, other apparatus had to be introduced to correct unavoidable variation on the auxiliary plant. The real trouble was that the auxiliary plant had been designed inadequately and had not enough control in the first instance; he considered that in some instances regulation of some kind was necessary, probably on small transformers driving auxiliary plant It might be A.C. auxiliary plant in the power station itself, or it might be converting plant in the sub-station system.

Another matter of very great importance, and which had been referred to briefly by the authors, was that in considering regulation on any system we could not think in terms of one. If we were making a change at any one point and had a bank of transformers there, the whole of the transformers in the bank must be synchronised so that there was parallel running between the transformers themselves. The authors had indicated and discussed some of the problems that would arise in the near future, and many engineers would find that the paper would be a very useful work of reference during the next few months.

Mr. J. N. ROBERTSON, replying to the discussion, agreed with Mr. Dawson that the tappings were not often used in colliery work. The manufacturers, he said, were not keen on putting tappings on transformers, because every tapping was bound to be a source of weakness. One 250 K.V.A. transformer which had been mentioned had about 30 tappings, and it looked like nothing on earth. Those tappings were not used, but they weakened the transformer. The colliery people, however, were just as guilty as the supply undertakings of asking for tappings which were never used. The authors had suggested that 2½% and 5% would meet all the requirements, and the reason given was that that would enable the change to be made from the summer to the winter load. His experience was that there were thousands of cases in which a transformer was installed and put on one tapping and left there, and nobody could say which tapping was being used. In colliery work particularly one could take off the top of the tank and change the tapping and put the top back again. One should not take the cover off or interfere with it in any way more often than was absolutely necessary. If the transformer was in a somewhat cramped position it was quite likely that a spanner would be dropped into it, unless the spanner were tied to the side of the tank, and if a spanner were dropped into it, it would have to be taken down. There were many remarkable things discovered in transformers that were returned to the shops.

Dealing with Mr. Morgan's suggestion that it was difficult to appreciate how the regulating apparatus described could be used in colliery work, he said the changing-gear equipment was certainly not yet developed to the stage at which it would be used in collieries. It was altogether new to this country but in a very short time it would be developed for use in collieries. After all, the collieries handled some very big units but they had not used the equipment yet because it was not available when those big units were installed. It was impossible to put a changing gear on a 1000 K.V.A. transformer; the switchgear would be bigger than the transformer itself.

He was not quite clear as to what Mr. Kingsbury had meant when he had asked what percentage variation was allowable on a transformer, i.e., whether he had meant the percentage of the steps or the total variation allowed. The Central Electricity Board's specification called for steps of 1.4%, with a maximum plus and minus of 10; i.e., a total of 20%.

As to the suggestion that, with a wide variation, there would be a good deal of circulating current, he said the actual range of voltage did not affect it in the slightest. It depended on the width of each step; no one, he imagined, would want to step more than 2% at a time, and with a 2% step there would be introduced either a choker, an auto-transformer, or an induction regulator. With either of those in circuit, the current that could flow from one tapping to another would be limited; there would be a little circulating current, but it would be choked back and kept within reasonable limits.

This statement would to some extent answer Mr. Cowie's question with regard to parallel running and phase displacement. There was no phase displacement at all in tap changing under load, though there was a slight change in ratio when changing from one step to another. A point to be borne in mind in connection with parallel running was that if one had equipment for tap changing under load, and if one transformer were running and another had to be put into circuit, it was necessary that both should be running on the same tapping. The Central Board called for an arrangement which, when an additional transformer was being put into circuit, would adjust it to run on the same step as the transformer already in circuit before the transformer switch could be closed. When there were two or more transformers in circuit, the step-changing gears were controlled by a master switch, so that any change was made in all the transformers at the same time.

With regard to flicker when changing, he said the extent of it must depend upon the percentage step between the tappings. On a power load one would never see it at all, but on a lighting load, if the load were very light, and if the step were long, it would be seen. It was usual, however, in the case of transformers for lighting loads, to call for narrow steps—of 1% or even lower, if necessary—and flicker could be avoided by introducing more and narrower steps.

It did not appear to be necessary for auxiliary units at power stations to have a fairly wide voltage range, because the tap changing was done on the step-up away from the station altogether, so that the power station bus-bar voltage was not affected; it was the load outside that was varying.

Replying to Mr. Horsley, he said the pressure at either end of the feeders could be controlled. Where there was a transformer, one could alter the ratio at any point; where there was no transformer one could use a booster gear.

MIDLAND BRANCH.

The Electrical Inspector's Annual Report.

Discussion.

At the meeting held in Mansfield on January 26th last, the Chairman (Mr. R. Wilson) indicated that a review of H.M. Electrical Inspector of Mines Report for the year 1927 would be presented by Mr. Wyness, by way of opening a general discussion. The Report ought to be in the hands of every one interested in colliery electrical work.*

Mr. W. WYNESS.

The Report begins with remarks re the steady increase in the use of electricity. The Tables following are very interesting and worth studying, but it was not that part of the Report they were to consider. Page 8 introduced that portion with which they were more actively concerned; accidents, their causes, and the lessons to be learned from them.

There were eleven fatal accidents attributable either directly or indirectly to the use of electricity, involving the loss of sixteen lives and serious injury to eight others. With one exception all these accidents occurred below ground. Seven cases were of electric shock, one of ignition of firedamp, one outbreak of fire, and two of a mechanical nature. This, the Report states, constitutes the most serious record since 1924.

Of the seven accidents due to electric shock, five are said to be due to the rashness or carelessness of the persons who lost their lives, and two to misadventure.

The ignition of firedamp is attributed to the omission of a fixing screw, said to be a common defect. The outbreak of fire could easily have been mastered if the men in the vicinity had not run away.

The coal cutter machineman who lost his life is said to have been partly guilty, inasmuch as that he failed to use the safety catch provided. The accident where a circuit breaker exploded was said to be due to the man's omission to fill the oil tank properly.

Mr. Horsley (H.M. Electrical Inspector of Mines) adds: "While it is not difficult, in most of these accidents, to find carelessness on the part of the victim, perusal of the accounts that are included in this Report will perhaps suggest that the organisation appears to rely unduly upon the discretion or knowledge of the individual workman." This comment is worthy of consideration. A Table (No. 6) follows giving statistics of the yearly deaths from shock as compared with the H.P. in use, also a Table (No. 7) giving the number killed each year under an occupational analysis; a third Table (No. 8) gives the nature of equipment involved in fatal accidents. Taking a ten year period, Switchgear is responsible for approximately 33%, Flexible Cable and Plugs approximately 26%, Overhead Lines approximately 20%, Motors and Transformers only 3½%, and Coal-cutting Machines the same. Accounts of the accidents then follow.

* Report of H.M. Electrical Inspector of Mines for the Year 1927 (J. A. Bernard Horsley). Price Sixpence. H.M. Stationery Office.

First, page 10.—This man could not be an "electrician" owing to age. He was therefore an "authorised person," competent for the purpose of the Rule in which the term is used. Evidently he was *not* competent, otherwise he would not have failed to insulate the defective conductor and close up the dividing box, and he certainly would not have been poking amongst 500 volt leads with one inch of water on the floor. This is one of the cases to which Mr. Horsley refers in his comments.

No. 2, page 11.—In this case it would appear that everything was done in a proper and careful manner until repair was effected and power switched on. It is doubtful whether the man had an afterthought about No. 3 cubicle and, not desiring to make dead again, knowingly took the risk, and lost.

No. 3, page 11.—This accident draws attention to a very serious danger, always possible where Edison screw lamps are used, not only in the Goliath size on high candle power lamps, but also on the small type as used in houses, especially where the four-wire system is in use. Great care may be taken to keep colour to colour throughout the system, but when coupling up the lamp holder, particularly if twisted flex be used, one is apt to get the screw socket on the live side.

Nos. 4, 5 and 6 may be grouped together; the actual occurrences were different, yet they all resulted in trailing cable trouble and in each case caused a loss of life. Mr. Horsley draws attention to the advisability of using a type of cable having an earthed metal screen surrounding the conductors, and to the use of leakage protection gear. Mr. Wyness said he preferred to leave these cases to those with experience of this class of machinery.

No. 7, page 14.—This somewhat unusual accident would never have occurred if Rule 134 (c) had been observed. The incident makes one realise how valuable the imaginative faculty is in any sphere of life, in moderation of course. Could the electrician have visualised the possibilities of his action when erecting the signal wires, this regrettable accident would never have appeared in the Report.

No. 8, page 15.—This case in Mr. Horsley's opinion is of some considerable interest, and some importance: it is of the type, no doubt, which has inspired M.D. Circular No. 31, in which certain suggestions are made. Those more familiar with coal face machinery will no doubt express their views on this case.

No. 9, page 16.—This case is very interesting, inasmuch as it raises some points of importance in view of the increase in K.V.A. of our supply due to the linking up of collieries. The actual incident is not an uncommon one: a fall of stone on to a cable is the cause of a short circuit. The result, however, was very serious. A fire occurred, three men lost their lives and ten others suffered more or less. The cable was 19/16 V.I.R. twin S.W.A. and jute braided overall. It was a branch cable jointed in a four-way box, the supply cable into the four-way box was of the same size and kind and was controlled in the pit bottom by a modern oil break circuit breaker. The supply pressure was 500 volts D.C. and eight motors with an aggregate H.P. of 234 were fed from this cable. By the way, if 50% of these motors were working at the same time and if each motor was carrying 75% of its rated load we get a current of 130 amps., approximately, and the drop appears as though it would be interesting. The circuit breaker in the pit bottom was provided with overload trips on each pole and these were set for 300 amps. plus 15%; no oil was put in the dashpots. The resistance of the circuit from the bus-bars of the power station switchboard to the place where the fault occurred is estimated to be 1.43 ohms Assuming a reduced voltage of 400 due to back E.M.F. of fault arc and low voltage of generator, the short circuit current may have been limited to 280 amps., which would be insufficient to trip the circuit breaker. This was evidently the case, as, when the cable was short circuited an arc was struck and maintained between the conductors sufficiently long to destroy completely, by electrical fusion, some nine yards of cable, both copper and steel. It is assumed that the arc was extinguished accidentally.

If the assumed H.P. given is anything near the truth, and also making allowance for occasional starting up of motors, one can understand why the trips were set so high, though all things considered it would appear impossible for the current ever to reach this figure.

The reason why this case has been recounted at unusual length is to draw attention to the subject of automatic protection and to illustrate a very common misapplication of such electrical safety devices. Rule 128 (c) was clearly contravened. A circuit breaker installed at the beginning of the branch circuit would probably have prevented this fire. Attention is drawn to the fact that overload protection alone, even when applied intelligently, cannot be relied upon to prevent an outbreak of fire resulting from a damaged cable. One might also draw attention to the fact that overload protection with an earthed neutral system suffers from the same disadvantage: it offers no protection until the leakage current is sufficient to operate the switch overload coils.

No. 11, page 19.—Here again we have a circuit breaker of the most modern type, no defect of apparatus, all switchgear and starter were O.K.

The suggestion is that the man omitted to fill up the oil tank, that on closing the switch sparking took place in air and initiated the short circuit between phases. It would appear sure that before this assumption was made, all the facts were carefully considered and the switch would be carefully examined; yet there is the doubt whether—supposing that insulating barriers were fixed between the phases and that the sparking contacts were of liberal size, also supposing the contacts were adjusted to make simultaneously—sufficient arcing could be set up, when closing the breaker, to initiate a short circuit.

Here again we have an illustration of the fearful power developed on short circuit when fed by large power plants. Here also we have a comment bringing home to the appointed electrician the extent of his duties as laid down in Rule 131 (a).

Some short accounts follow of ten cases of non-fatal accidents.

No. 1 was a case of firedamp ignition, and no apparent cause can be discovered; the electric coal cutter working there was, however, withdrawn.

No. 2.—Ignition of firedamp was attributed to the switching off of a coal cutter. A missing set screw allowed gas to enter the switch-chamber and gas was ignited by the break flash.

No. 3.—A coal-cutter trailing cable was dislodged. fell on to the cutter chain and was drawn into cut and severed by picks. Arcing occurred and firedamp ignited.

No. 4.—A fall of roof, a damaged armoured cable, a short circuit, and the firing of the cable insulation. In this case the circuit breaker was provided with overload trips, also a non-selective leakage trip device set to operate with a leakage current between mid-voltage point and earth of half an ampere. The breaker was found to have tripped, the copper conductors of the cable were fused apart, the wire armour was also parted about a yard beyond the point where the cores were fused, and the steel wires were fused. It appears that the armouring became involved in the fault at a later stage of the development, so that sufficient heat was developed to start the fire before the leakage device operated.

No. 5.—A short circuit in the stator windings on a 3000 volt 50 H.P. induction motor. Three breakers were tripped, the local one set at 25 amps. without retardation, those at the back set at 150 amps.

Nos. 6 and 9.—Short circuits on air-break, two-way starting switches for a 7.5 H.P. 3-phase 500 volt motors. One switch burst, the other had bulged plate.

No. 7.—Attendant withdrawing a 2750 volt draw-out switch when cover plate burst and injured man with burning oil. Short circuit between connections.

No. 8.—Starting a 3300 volt squirrel motor, a short circuit on motor caused explosion: tank was torn from switch, top was compound filled and held. Calculated short circuit at fault was 40,000 K.V.A.

No. 10.—Electrician attempted to open an isolator prior to changing over. The only load at the time was the magnetising current for a 3-phase 1000 K.V.A. transformer connected to turbo-generator on 500 volt side, but open circuited on 10,000 volt side.

The latter end of the Report deals with the "danger" from "live" electrical conductors during examination, test and repair, and draws attention to M.A.C. 23.

Regulation 131 (g) reads: "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. While lamps are being charged the pressure shall be cut off."

Several instances are given of accidents caused through non-attention to this Rule.

No. 1.—Mistaking *live* sockets of draw-out switch for *dead*.

No. 2.—Overhead mains fed by two stations. Made *dead* at one station but forgot to make *dead* at the other.

No. 3.—Lowering oil tank of circuit breaker whilst incoming contacts were *alive*. Man had no written authority.

No. 4.—Ring main fed from same switchboard. Opened one end but forgot dual feed. Withdrew circuit breaker and tried flicking contact sockets with piece of cable.

No 5.—Two-way fuse box, electrician about to work on one feeder removed fuses; unfortunately he removed the wrong fuse.

No. 6.—

No. 7.—Fan motor supplied by two lines through a selector switch. Fault developing, both lines were made *dead*, electrician repairing defective selector switch when one line was made *live*.

No. 8.—Draw-out switch opened and withdrawn to facilitate tests on a cable; man flicking sockets of switch to earth outgoing cable touched wrong sockets. This is a similar case to No. 1.

These accidents are divided into two classes: First, cases where work is begun or resumed upon conductors which are (erroneously) supposed to be *dead*, without first earthing the conductors. Secondly, cases where the electrician proceeds to earth a circuit that he imagines is isolated, by flicking contacts which are in fact *live*, with the fuse end of a short length of cable connected at its other end to "earth."

With regard to the latter system, M.D. Circ. 23 states that it is not safe and that it should be prohibited. I agree; the fact of a man "flicking" shows that a doubt exists in his mind whether what he has already done has made the circuit *dead*. I am sure you will all agree that no such doubt should exist. How remove the doubt?

First, simple circuit diagrams of the electric system, and of the important parts of a system should be available, blue prints of switch panels should also be available to enable a man to refresh his mind as to the construction of the particular gear he is about to work on. Case No. 1 bears out this, where the electrician is supposed to have forgotten that whereas for the outgoing circuit the upper contacts were connected to the bus-bars for the incoming circuit, these were the live contacts.

Second, after clearly grasping the particulars of the circuit about to be worked on, make sure that it is *dead*.

Third, earth the conductor or conductors.

Fourth, don't forget to remove the "earth" before making the circuit "live."

It is suggested that in spite of all our care blunders will occur. Admitted, yet this is no reason why all possible precautions should not be adopted.

This portion of the Report is to discuss the principle advocated in the M.D. Circ., which is that the circuit shall be put to earth through a circuit breaker, so that should the circuit be live from any other source it would be equivalent to closing the breaker on a short circuit; this will without doubt safeguard the operator from working on a short circuit, but introduces a danger such as we read of at Glamorgan in Case 11, at Northumberland in Case (c) 6 and 9, and again in Glamorgan in Case (c) 8. These refer to the bursting of the breaker due to the heavy rupturing K.V.A. This is a factor which must be faced for many years to come owing to the many switches which will remain in use and which are not designed to withstand the heavy strain which short circuits produce under modern supply conditions.

There is one fault condition which would not be covered by this system, i.e., faults in the circuit breaker itself. However, tribute is due to the masterly manner in which the subject has been treated and to express appreciation for the valuable information contained.

The remainder of the Report consists of Tables which do not offer subjects for discussion.

Mr. Wyness, concluded his address in the following terms: "Well, Gentlemen, I do not know how this Report may appeal to you; for my own part I am grateful to Mr. Horsley for the information it contains; every case described contains a lesson and most cases contain a warning. It is not given to everyone to be able to visualise the consequences of all his sins of omission and commission. I am sure that in many of the plants where these accidents occurred we should find a well kept modern plant, and one might with all sincerity say 'There, but for the grace of God, would be myself.' Take Case No. 2: how many of us have not at times taken risks which may possibly have had such an unhappy ending? Case No. 9: if we are honest, how many of those present in setting the overload coil trips have taken into consideration the resistance of the cable connected, with the object of ascertaining the maximum short circuit current possible to flow? Case No. 11: how many of us have taken into consideration as the supply to our colliery has been increasing in magnitude, how we stood in regard to the rupturing capacity of the switchgear, much of which has been installed many years? No, I feel sure you will agree that each case we have considered contains some lesson which all of us may take advantage of. The Report as a whole must stir up its readers and help to eliminate some point which we were neglecting, give us a new view point on some of our duties, make us determined not to take anything for granted; in brief, 'Help to raise the status of the Colliery Electrician.'"

Mr. WILSON said he believed they would all agree with the general opinions expressed by Mr. Wyness. He had said a great deal to encourage serious thought. To Mr. Wilson the worrying factor was: what are we going to do to prevent these accidents in the future, and what guarantee can we give that we ourselves will not be involved in some similar trouble? The only thing to do was to study the Report and take such steps as experience and knowledge would dictate. Take trailing cables. Mr. Horsley suggests in his Report that he preferred the type where all the cores are armoured. Some of the members have had experience of the type Mr. Horsley has in mind. They would remember that previously Mr. Horsley suggested what he calls "pliable armoured cables," but there were certain objections to these. It would be interesting if some with experience of this type of cable would give views on the subject. Ordinary trailing cables are by no means satisfactory to-day. No one felt really safe with them, but the future would be determined by the experience being gained at the present time.

Mr. GRICE.—The part which is most interesting in the report is mentioned on page 25, dealing with the danger from live electrical conductors during examination and repairs. As Mr. Wyness remarked, a circular was issued some time ago by the Mines Department showing how this object was to be attained, and though this particular method of earthing the cables whilst in repair may be all right he, Mr. Grice, was at a loss to see how it could be applied in all cases, especially in old types of switchgear not of the draw-out type. Again, of course, there was the danger from switches blowing out on short circuit. He was no advocate of the flicking method, but was concerned about an alternative safer method.

Referring to the automatic tripping of circuit breakers, Mr. Grice said if they were going to use the same breaker for this earthing business they would have to make it fast after it was put in. If it was a draw-out switch he could not see how one could make a mistake unless by getting the wrong cable. That was one of the risks that had to be taken. The C.M.A. dealt with these automatic switches and says they are not to be interfered with, and yet they were advised to make that interference.

Mr. PIDCOCK.—Coal cutters are left on the face until they actually break down. It ought to be possible to take a machine into some place underground where missing nuts, etc., could be replaced.

Mr. WILSON.—One has always to be on the economic side and to learn to manage with gear which will just carry on, and so long as it does carry on it is all right. Manufacturers to-day were very often in doubt as to what the rupturing capacity was. They would give a figure, but it was another matter to prove it.

Mr. NORTHCOTT.—The method suggested by the Mines Department is very cumbersome. There are two criticisms of it: one, should you happen to close it when the circuit is alive; and the second, the additional cost. There must be some definite method of ensuring what a circuit is before starting work on it. Could one not have small key diagrams showing how it was connected up and how it could be made dead?

Mr. WILSON.—Here we are with all these highly complicated and costly plants, yet in spite of all, we have these increases in accidents. Surely it should make us wonder whether we are on the right lines. Would it be better to cut out a lot of these instruments and rely on a better type of man?

Mr. F. SMITH, referring to the number of deaths from shock, said in the majority of cases the injured man had been left too long before being subjected to artificial respiration. He, personally, felt that the colliery electrician ought to take a course of ambulance so as to be able to administer artificial respiration.

Mr. RABDALL thought that instruments placed outside the switch were a source of danger.

Mr. WILSON said that practically all the questions raised were affected by economic conditions.

Mr. F. SMITH said he had very great pleasure in proposing a vote of thanks to Mr. Wyness for his paper, which was very useful and instructive.

Mr. GRICE, in seconding, said he was quite sure Mr. Wyness had spent many hours of careful study in compiling his criticisms, and their thanks were due to him that afternoon. Mr. Wyness briefly responded.

Messrs. W. BAMFORD and L. G. F. ROUTLEDGE (written communication).—We would like to say how much we appreciate Mr.. Wyness' remarks in opening the discussion on the Electrical Inspector's Report for 1927. The annual reports are extremely instructive, interesting and valuable. Mr. Wyness has raised a number of points chiefly on the organisation of one's system and the character of the staff to maintain it. It occurs to us that the tables at the beginning of the reports, whilst they show the growth of the employment of electrical energy at mines, do not show how the various applications, which are classified, have increased, and when considering the fatal accidents it would be useful to know how the coal face machinery has increased in comparison with other applications. From our experience we would expect most accidents to occur with face machinery and trailing cables, and are rather surprised at the number with switchgear which shows that either switchgear in use is of obsolete type, not of sufficient capacity, or developments are not being taken advantage of.

It would be useful to have a column in the statistics showing units generated or consumed at collieries, if possible with some idea of the power consumption of the various classifications.

We have in mind the following three cases:—

(1) A group of small collieries turning a single shift, 233 stationary motors, 100 electric coal cutters, 20 face and gate conveyors (on the increase). Consumed 6½ million units in 1928.

(2) A single colliery, 80 stationary motors, no electrical machinery at or near the coal face, turning a double shift. Consumed 6¼ million units in 1928.

(3) A new colliery still developing turning 1½ shifts, 60 stationary motors, consumed 6¼ million units in 1927, 8¼ million in 1928.

All the above relate to A.C. plant. The third case also consumed in 1928 1½ million units for electric winding D.C.

The duties of the electrical staff are far more arduous in the case of No. 1 than in either Nos. 2 or 3; and with regard to case No. 1, thin seams far out, the economic question is a continual handicap. Cases 2 and 3 do not offer any serious problems provided suitable switchgear with proper rupturing capacity is installed, and the staff do not attempt to work on live circuits, accidents should not happen.

Trailing Cables.

Our Chairman specially asked us for our experience on trailing cables. Here in our opinion is the weak link in the whole electrical chain from generator to face apparatus, and finality has by no means been reached.

The type (a) mentioned near the bottom of page 12 is theoretically a sound proposition. In actual practice it does not come up to the desired expectations. Practical conditions, the peculiar job of the trailing cable and manufacturing details militate against the ideal being realised. We have tried all the various improvements which have appealed to us, only to be disappointed with the results.

Where we have had cables of the C.T.S. type, all the conductors sheathed, surrounded with a ferflex braid, and sheathed overall, we have found that in a very short time the ferflex began to fracture all along the cable. The small increase of resistance due to this caused the cable to be quite useless for the Williams-Rowley system.

Considering the wires of the ferflex were too large and not of sufficient flexibility we had the number of wires increased and the gauge decreased. These cables lasted somewhat longer than the former but the same trouble took place. Another type was then tried, each power conductor (or core) was surrounded with a metallic sheath consisting of fine flexible copper wires, and these metallic sheaths all lay in direct contact with an uninsulated centre earth core.

One of these cables got entangled in the haulage gear of a coal cutter; open sparking was observed and the leakage protective device operated and cut off the energy. The protective gear was found to be in good order.

This type of cable was kept under close observation. After having been in use only a few months one of the power cores went to earth. The fault was found to be several yards from the machine end.

The cable was opened out, the metallic sheath was fractured in places and wires had penetrated through to a power core. It was also found that the sheath was fractured about every three feet right through the cable. Other cables of this type are following suit. Free sulphur in the sheathing might have some effect on the small gauge metallic shrouding. We have found that the free sulphur is about half of 1%. These trailing cables are very expensive and the troubles very serious from the economic side. Satisfactory repairs are also a great difficulty.

It seems to us at the moment the best proposition is a 3, 4 or 5-core cable, the cores laid on to a bed of 75 or 80 mils and sheathed to a radial thickness of 250 or 300 mils. Two of these cables can be bought for the price of one of the ferflex sheathed described above and consequently there is a better opportunity to have enough spares to enable all the cables to come to the surface periodically for proper overall.

There is still the possibility of broken strands of haulage ropes penetrating the sheath, a serious danger if the wire reaches a core, and it remains to be seen whether thickening up the sheath or employing the (b) cable (page 12) will overcome this danger.

Much damage occurs to trailing cables when not actually in use for cutting operations, and arrangements should be made either by means of bollards or portable reels for the better preservation of the cables. We have in use several small drums mounted on pit tram type bogies; the cables are wound on these when not in use, and are moved from point to point if so required on the drums. The results obtained are promising. We are sure other members can give us some observations on their experience which should be extremely useful.

We had, a few years ago, the opportunity of testing the standard pummel, and the results obtained were very satisfactory.

With regard to conveyors; these appear to be, or rather the arrangement of them, still in the experimental stage. The question whether the driving gear should be at the delivery end or the other end does not seem to be decided, and until it is decided it is difficult to make definite arrangements for control and protection. If all the driving gears could be installed at the delivery end an efficient method of central control with all the protective features desired could easily be set out.

Remote control for coal cutters, although expensive and experimental, is worth attention. Making and breaking the circuit in a flame-proof gate-end box of efficient design would seem to be a much better system than any at present in operation, and would have a great tendency to reduce accidents. Those at present on the market appear to be too elaborate and complicated, simple defects might cause a serious loss of output.

A point Mr. Wyness rather emphasised was that the fatalities seem to show faulty organisation and lack of proper instructions to staff. This seems to us very real and has inherent difficulties hard to overcome.

Some imagination on the part of the electrician-in-charge would be an invaluable factor—he would visualise possible accidents and take means to prevent them; he would study his staff with a view to relegating certain duties to certain men best fitted to carry them out, and he would as far as he possibly could always make a personal final inspection of any apparatus going into use for the first time.

A lot could be said on the subject of lack of thought and temporary mental aberration. We are not free from it ourselves, and to anyone with any observation, humanity is plainly full of it. We have had live cables cut into with hacksaws after other adjacent cables have been made dead for the purpose, and no serious difficulties were in the way of tracing the cables.

The earth cores of trailing cables have been connected to the live socket at the gate-end box and to the earth socket at the coal cutter. The leakage protective system prevented operation of the apparatus.

Another example—a D.W.A. cable 110 yards long being jointed, the whole of the armouring would not go comfortably into the glands. The man at one end cut back the outer layer, the man at the other end the inner layer. There was a tape wrapping between. Result, earth continuity broken. Luckily no accident occurred although the coal cutter drivers got shock.

If we personally had to work on an overhead line, we should lock off all the necessary switches and in addition earth and short the line adjacent to the point to be worked on. This is a vital point, the necessity of which does not seem to us to be sufficiently realised.

It seems to us that at the ordinary size colliery, circuits in parallel (except shaft cables) should be avoided wherever possible.

As regards protecting oneself when working on a cable, the means advocated in Mines Circular 23 is a step in the right direction, but the switch should not be automatic in case of damage when closing on a short circuit. It should be left for the next switch towards the point of supply to open.

There is a great likelihood of the extension plugs being fixed on to the wrong positions. It does not eliminate the human element, and is subject to the economic conditions always with us.

Rupturing Capacity of Switchgear.

Mr. Wyness laid great stress on this important factor and we entirely agree with him. With future possibilities of being connected to the National Grid, one's switchgear under short circuit conditions may have to deal with very large amounts of power, and with reasonable sized power plant behind it, it has to do so at the present time.

The economic question is a serious obstacle, for switchgear of suitable rupturing capacity may cost two, three or four times the value of the apparatus it has to protect.

WARWICKSHIRE & SOUTH STAFFS. BRANCH.

At the meeting of this Branch held in the Technical College, Hednesford, on February 21st last, a paper entitled "Low Grade Fuels and their Utilisation for Steam Raising" was read by Mr. B. Samuels. The subject was dealt with by its exponent in an extremely practical and detailed form, and members took considerable interest in the lecture, the lantern illustrations of incidental plant and also in the test reports which were projected on to the screen. Mr. Samuels replied very fully to the many questions which were raised following the reading of his paper, and the Chairman, Mr. F. J. Hopley, moved that a vote of thanks be accorded to the speaker and also to Mr. Hargrove, who added his experiences to the enjoyment of all present. Mr. I. T. Dixon supported the resolution, which was heartily carried.

Low Grade Fuels and Their Utilisation for Steam Raising.

B. SAMUELS.

This subject is one which for many years has attracted considerable attention and in which the interest has been intensified very much since the War. It is desirable to have a clear understanding as to what is meant by the term "low grade fuel." The deciding factor as to whether a fuel comes in this particular category is not directly dependent upon its composition, but upon its market value. This, in turn, is dependent on the service that can be obtained from the fuel. Progress is constantly being made in the design of boiler furnaces to increase the range of fuels that can be burned satisfactorily and, as a consequence, fuels which at one time had little or no market value, come into demand and no longer remain under the category of "low grade." Some who have still many years to go before qualifying for the old age pension could remember when a bituminous nutty slack coal having a calorific value of 12,000 B.Th.U. was considered low grade. In fact, even since the War, nutty slack coals of 11,000 and 11,500 B.Th.U. have been described as "low grade." In these days, any coals of this description are considered good quality.

The subject is so wide that it is necessary to limit this paper to a consideration of one section only. It is proposed, therefore, to deal only with solid fuels which have been mined; and include a reference to solid fuels produced from the treatment of coal. Further, the tendency in recent years has been in the direction of concentration of steam production into a smaller number of plants and larger units. This, together with the necessity for minimising labour costs, has led to an increase in the use of the water tube type of boiler and mechanical stoker. The external type of furnace, constructed of refractory material, facilitates the use of low grade fuel, as also does the facility thus provided for constructing large combustion chambers. Attention will therefore be confined here to this type of boiler and the two methods of firing at present available—that is to say, on mechanical stokers and in pulverised form.

Dealing first with stokers, many types of stokers have been employed. One of the earliest forms was the chain or travelling grate type introduced by Juckes fully 88 years ago. This type of stoker has been developed very considerably by different makers and is now used very extensively. Although other types have given, and are still giving, good service with water tube boilers, the position to-day is that this is decidedly the most favoured type of grate for burning low grade fuels in these circumstances.

The principal characteristics of coal, etc., which have presented difficulties in their efficient utilisation with this type of stoker are:—

(1) High ash content.
(2) Small proportion of volatile matter.
(3) Low quality of volatile matter.
(4) Smallness.
(5) Low caking properties.
(6) Very hard caking properties.
(7) Deterioration due to weathering over a considerable period.

We will briefly consider the progress that has been made in overcoming these difficulties.

High Ash Content.

With two classes of fuel high ash content is found: in slack coals containing a large quantity of shale; and in a very low grade form of slaty coal. With the former it frequently happens that, owing to the quantity of impurities, the fuel does not cake. With the earlier types of travelling grate, which employed suction draught only, such fuels could not be ignited satisfactorily. In the first instance, modifications to the arch design increased the range of such fuels that could be dealt with. These modifications consisted of replacing the plain arch over the front portion of the grate by an arrangement whereby some of the hot gases were led over the incoming fuel, through a small flue at the front end of the arch, and thence over the arch into the combustion chamber.

The next step was the introduction of forced draught, sometimes in the form of a closed ashpit and sometimes in a series of compartments under the surface of the grate for the purpose of controlling the air supply to different portions of the grate throughout its length. Further developments have taken the form of the introduction of rear arches.

An instance of a coal high in ash being burned satisfactorily on mechanical stokers is at the Prince's Power Station, Nechells, of the Birmingham City Electric Supply. Here the coal contained 23% of ash on the dry basis. Particulars of an official test carried out on this plant are given in Table I.

An example of a slaty coal is at Budapest, where the fuel contained 26% of ash on the dry basis. In this case, there is the additional disadvantage that the volatile matter is low in value, as is shown by the fact that the gross heating value of the dry ash-free fuel is only just over 12,000 B.Th.U., as compared with the normal figure for an ordinary coal of 14,000 to 15,000 B.Th.U. The overall efficiency shown here (see Table II.) is not so high as in the former case, but this is largely due to the total heating surface of the combined plant not being designed for so low a final gas temperature.

Another example of shale is an Oil Shale from Dorset. In this case, the ash content on the dry basis is over 39%, but the volatile matter is, of course, of better quality, the gross value of the dry ash-free fuel being nearly 14,000 B.Th.U. In this case the efficiency recorded is again lower (see Table III.), but it will be seen that the plant included boiler, superheater and furnace only.

Small Proportion of Volatile Matter.

Owing principally to the difficulty of maintaining ignition where the volatile content is low, the burning of Welsh coals and others having this quality, on mechanical stokers, was not successfully carried out until many years after the general adoption of mechanical stokers. As a result of considerable experimenting, a special setting was designed, which enabled coals containing down to 12% of volatiles and in some cases rather less, to be burned successfully with suction draught only. The introduction of forced draught has rendered this special setting no longer necessary for these particular coals and, with the compartment control and special furnace settings now available, coals are being burned containing only about 5% of volatile matter.

Coke breeze comes under this heading. With the improvements in design of high temperature carbonising plants, the percentage of volatile matter contained in coke has been getting progressively lower and, in some cases, this is nowadays only 2% or even less. Coke breeze containing 6% to 10% of volatile matter, formerly often met with, could be burned successfully on the ordinary front arch stoker with compartment forced draught, but the lower volatile presented further difficulty, which has, however, been overcome by a special design of setting, which will be illustrated. The test shown in Table IV. indicates what has been done on such a plant.

With the introduction of low temperature distillation plants there will, in some cases, be low temperature coke available for steam raising purposes. This is already being burned quite successfully as delivered direct from the retorts to chain grate stoker hoppers.

Low Quality of Volatile Matter.

This occurs in lignitic fuels. Whilst in this country there are some rich deposits of lignite, they are not at present being worked. We, however, have the satisfaction of knowing that, when this is done, there will be no difficulty in burning the fuel successfully, as is clearly shown by some tests with Grecian lignite (Table V.). The efficiency recorded here, when considered on the basis of the net calorific value, may appear high, but it will be seen from the figures that the plant on which this test was made is a very comprehensive one, the temperature of the final gases being reduced to below 220 deg. F.

Smallness.

Where it does not contain a very high percentage of ash and there are reasonable caking properties, coal with a high percentage of fines can be burned satisfactorily without the aid of forced draught but, where there is little or no caking, the coal is not so easily handled. However, with the introduction of forced draught, the difficulty is in a very great measure overcome.

A local example of burning fine coal is at the Wolverhampton Laundry. Particulars of a test carried out on that plant are given in Table VI. It will be noted that the test was of 24 hours' duration, to determine the loss due to banking when the plant is out of service; also that a separate record was obtained for the working period, to indicate the efficiency under these conditions.

The Table VII. gives results of another test in which very fine coal was burned successfully, and in this case it will be noted that the proportion of fines which would pass through ⅛in. meshes was practically 50%.

In cleaning coal there is produced, however, a certain amount of very fine coal which still presents difficulties. With the washing process, this is in the form of slurry or washery settlings. Owing to their extreme fineness, not only are there difficulties in obtaining combustion on a mechanical stoker, but also in mechanically handling the fuel. In some instances where this coal is granular, it can be handled but, with the very fine slurry, the best means so far available for burning it is on a hand-fired grate. However, the quantity available has not, so far, warranted the expense that would be involved in making experiments and designing the necessary mechanical devices for overcoming these troubles. Alternatively, the fuel can be dealt with in a pulverised fuel furnace, to which reference will be made later. With the dry cleaning process, there is also a quantity of fine dust produced, and the best way to deal with this is in a pulverised fuel furnace.

TABLE I.

Report on Test made on Complete Boiler Unit (No. 6) at the City of Birmingham Electricity Department's Princes Power Station, Nechells.

Particulars of Plant.	
Boiler, B. & W. L.T.M. Heating surface ...	5,348 sq. ft.
Superheater Heating Surface	1,800 „
Economiser, B. & W. Superposed: Heating Surface	3,393 „
Stoker, B. & W. closed-in Chain Grate: Grate area	224 „
General Data.	
Date of Trial	June 4th, 1924
Duration	7 hours
Fuel.	
Kind used	Littleton nutty slack
Analysis of fuel as fired:—	
Moisture	14.40%
Volatile Matter	26.62%
"Fixed Carbon"	39.29%
Absolute Ash	19.69%
	100.00%
Total Carbon	50.75%
Hydrogen	3.46%
Gross Calorific Value of fuel as fired ...	9,407 B.Th.U.
Nett „ „ „ ...	8,927 „
Consumed per hour	5,865 lbs.
Ash and Clinker.	
Total Ash and Clinker per hour	1,166 lbs.
Percentage of fuel fired	19.88%
Analysis—Combustible	10.1 %
Absolute Ash	89.9 %
	100.0%
Steam.	
Average Gauge Pressure	317 lbs./sq. in.
Final steam temperature	678° F.
Water.	
Evaporated per hour	36,401lbs.
Temperature entering economiser	159° F.
Temperature leaving economiser	252° F.
Evaporation per lb. of fuel	6.21lbs.
Flue Gases.	
Temperature entering economiser	564° F.
Temperature leaving economiser	381° F.
Analysis by volume at economiser outlet—	
CO_2	13.0%
CO	Nil.
O_2	5.8%
N_2	81.2%
	100.0%
Boiler House Temperature	79° F.
Draught.	
At economiser outlet	.766ins.
At boiler outlet	.58ins.
Heat Account.	
Heat utilised per lb. of fuel	85.77%
Heat lost in chimney gases	8.13%
Heat lost in combustible matter in ashes	3.27%
Balance of account, due to errors of observation, radiation, etc.	2.83%
	100.00%

TABLE II.

Report of Tests carried out at The Ganz Wagon Works, Budapest.

Plant.		
Boiler Heating Surface		2,530 sq. ft.
Superheater Heating Surface		430 „
Air Heater „ „		4,734 „
General Data.		
Date of test	25-9-28	27-9-28
Duration	6 hours	6 hours
Fuel.		
Kind used		Tata Banya
Analysis of fuel as fired—		
Moisture	15.30%	14.80%
Volatile matter	33.37%	33.48%
"Fixed Carbon" ...	29.39%	29.23%
Absolute Ash	21.94%	22.49%
	100.00%	100.00%
Gross Calorific Value of fuel	7,691 B.Th.U.	7,720 B.Th.U.
Nett Ditto.	7,209 B.Th.U.	7,245 B.Th.U.
Fuel fired per hour	4,023lbs.	3,751lbs.
Water.		
Feed water temperature ...	123° F.	111° F.
Evaporation per hour	18,850lbs.	17,466lbs.
Evaporation per lb. of fuel	4.69lbs.	4.65lbs.
Steam.		
Gauge pressure	103lbs. sq. in.	101lbs./sq. in.
Final temperature	529° F.	549° F.
Total heat of steam above feed	1,229 B.Th.U.	1,249 B.Th.U.
Air.		
Air temperature into air heater	73° F.	73° F.
Air temperature leaving air heater	336° F.	327° F.
Gases.		
Temperature leaving boiler	606° F.	579° F.
„ Air Heater	475° F.	460° F.
CO_2 leaving Air Heater ...	12.3%	12.6%
Heat Account.		
Efficiency	78.0%	78.1%
Gas Loss	11.4%	10.7%
Balance of Account—Radiation and other unmeasured losses	10.6%	11.2%
	100.0%	100.0%

TABLE III.

Report on Trial made at the Bath Tramways Power Station burning Oil Shale from Portisham, Dorset.

Plant.	
Type of Boiler	B. & W., W.I.F.
Heating surface	3,140 sq. ft.
Superheater heating surface	339 sq. ft.
Type of Stoker	Chain Grate
Grate Area	65 sq. ft.
Fuel.	
Kind used	Oil Shale (Dorset)
Weight consumed per hour	1,863lbs.
Gross Calorific Value as received	7,682 B.Th.U.
Proximate Analysis—	
Moisture	8.55%
Volatile matter	46.09%
"Fixed Carbon"	9.42%
Absolute Ash	35.94%
	100.00%
Consumed per sq. ft. of grate	28.7lbs.

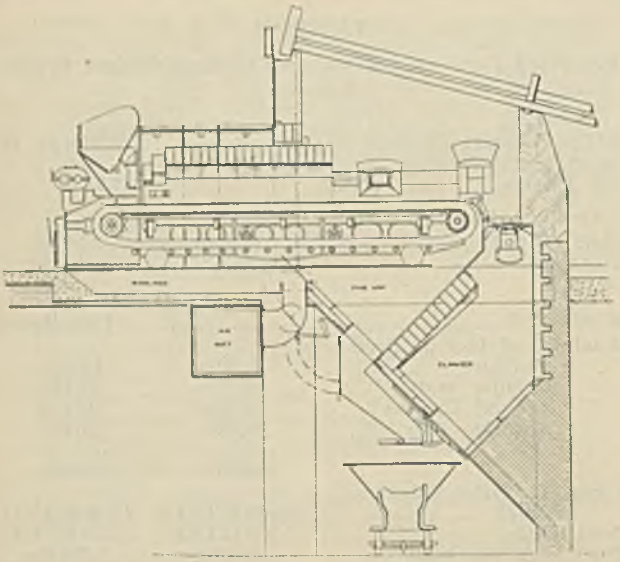


Fig. 1.—Forced Draught Chain Grate Stoker. Closed Ashpit Type.

STEAM.

Average gauge pressure	125lbs./sq. in.
Superheated temperature	490° F.

WATER.

Temperature entering boiler	162° F.
Evaporated per hour	9,120lbs.
Evaporated per lb. of fuel (actual)	4.9lbs.

FLUE GASES.

Average percentage of CO_2	11.0%
Suction draught (average)	.3ins.

THERMAL EFFICIENCY.

Efficiency of Boiler, Superheater and Furnace ...	72.5%

TABLE IV.

Test on Boiler Plant burning Coke Breeze on Chain Grate Stokers.

GENERAL DESCRIPTION OF PLANT.

One 3-drum W.I.F. type Boiler, heating surface	5,370 sq. ft.
One Superheater, integral with Boiler, heating surface	1,320 „
One Green's Economiser, heating surface ...	2,040 „
One Double Chain Grate Stoker (with special setting)—Dimensions	2 × 14′ 0″ × 6′ 0″
Grate area	168 sq. ft.

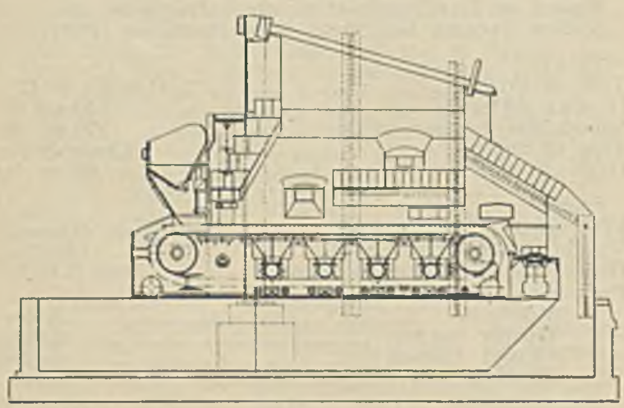


Fig. 2.—Forced Draught Chain Grate Stoker. Compartment Type with setting for Low Volatile Fuels.

GENERAL DATA.

Duration of trial	24 hours

FUEL.

Kind used	Coke Breeze
Proximate Analysis—	
Moisture	22.65%
Volatile matter	2.00%
"Fixed Carbon"	60.45%
Ash	14.90%
	100.00%
Gross Calorific Value of Coke Breeze as fired	8.996 B.Th.U./lb.
Ultimate Analysis:—	
Moisture	22.65%
Carbon	59.40%
Hydrogen	0.50%
Oxygen	0.98%
Nitrogen	0.77%
Sulphur	0.80%
Absolute ash	14.90%
	100.00%
Fuel fired per hour	3,645lbs.
Fuel fired per sq. ft. of grate per hour	21.7lbs.

WATER.

Evaporation per hour	20,576lbs.
Temperature entering Economiser	89° F.
Temperature leaving Economiser	167° F.
Evaporation per lb. of fuel fired	5.65lbs.

STEAM.

Average gauge pressure	70lbs./sq. in.
Final steam temperature	573° F.

FLUE GASES.

Temperature at Economiser outlet	360° F.
CO_2 at Economiser Outlet	11.4%

AIR AND DRAUGHT.

Suction *ex* Boiler	0.31″ w.g.
Forced draught pressure in Air Ducts	1.44″ w.g.
Temperature of air entering F.D. Fan	51° F.

HEAT ACCOUNT.

Efficiency of Boiler, Superheater and Economiser	79.4%
Chimney loss	13.7%
Balance of Heat Account—Radiation, loss in ashes and other unmeasured losses	6.9%
	100.0%

TABLE V.

Report on Tests with Grecian Lignite.

PLANT.

Boiler, B. & W. C.T.M. heating surface	10,028 sq. ft.
Superheater—Integral „	3,526 „
Economiser—Green's Tri-tube heating surface	6,552 „
Air Heater—Usco, heating surface	19,140 „
Stoker—B. & W. double compartment, grate area	360 „

FUEL.

Kind used	*Oropus Lignite.*	*Aliveri Lignite.*
Proximate Analysis, as fired—		
Moisture	19.70%	23.70%
Volatile matter	35.33%	37.16%
"Fixed Carbon"	33.41%	27.85%
Absolute Ash	11.56%	11.29%
	100.00%	100.00%

Gross Calorific Value, B.Th.U./lb.	8,014	7,340
Nett Calorific Value, B.Th.U. lb.	7,541	6,834
Weight used per hour ...	12,768lbs.	13,328lbs.
Weight used per sq. ft. grate area per hour ...	35.46lbs.	37lbs.
ASH AND CLINKER.		
Weight recovered per hour	1,204lbs.	1,148lbs.
Percentage of fuel fired ...	9.42lbs.	8.62lbs.
Proximate analysis:—		
Volatile matter	1.7%	3.7%
"Fixed Carbon" ...	5.5%	4.8%
Absolute Ash	92.8%	91.5%
	100.0%	100.0%
WATER.		
Mean temperature entering economiser	151° F.	166° F.
Mean temperature leaving economiser	242° F.	253° F.
Evaporated per hour	71,947lbs.	69,258lbs.
„ per lb. of fuel ...	5.63lbs.	5.20lbs.
„ per sq. ft. of H.S. per hour	7lbs.	6.91bs.
STEAM.		
Average gauge pressure ...	211lbs. sq. in.	206lbs./sq. in.
Final temperature	581° F.	578° F.
FLUE GASES AND DRAUGHT.		
Temperature leaving boiler	537° F.	538° F.
Temperature leaving economiser	338° F.	346° F.
Temperature leaving air heater	216° F.	219° F.
CO_2 at boiler outlet	13.4%	13.8%
CO_2 at air heater outlet ...	10.4%	11.3%
Air entering heater	108° F.	108° F.
Air leaving heater	240° F.	245° F.
Draught at boiler outlet ...	.44" w.g.	.41" w.g.
„ economiser outlet	.60" w.g.	.57" w.g.
„ heater outlet	1.13" w.g.	1.12" w.g.
HEAT TRANSMISSION.		
Per square foot of		
Boiler H.S. per hour ...	7,103 B.Th.U.	6,759 B.Th.U.
Superheater „ ...	2,152 „	2,066 „
Economiser „ ...	999 „	920 „
Air heater „ ...	182 „	174 „

HEAT ACCOUNT (on Gross Calorific Value).

Thermal Efficiency of Unit	83.5%	82.8%
Chimney loss	9.3%	10.1%
Heat lost by combustible in ash	1.2%	1.5%
Balance—Radiation and unaccounted	6.0%	5.6%
	100.0%	100.0%

HEAT ACCOUNT (on Nett Calorific Value).

Thermal efficiency of unit	88.7%	88.9%
Chimney loss	3.6%	3.4%
Heat lost by combustible in ash	1.3%	1.6%
Balance—Radiation and unaccounted	6.4%	6.1%
	100.0%	100.0%

TABLE VI.

Test at Wolverhampton Laundry.

DESCRIPTION OF PLANT.

Boiler—B. & W. W.I.F., heating surface	2,852 sq. ft.
Superheater—Heating surface	415 „
Stoker—B. & W. Balanced Draught:	
Dimensions	6' 6" × 10' 0"
Grate area	65 sq. ft.

GENERAL DATA.

Date of test	May 19th, 1922
Duration of test	7-16 a.m.—5-30 p.m.
Steaming periods	8 a.m.—1-0 p.m.
	2 p.m.—5-30 p.m.

FUEL.

Kind used	Shott End Fine Slack
Proximate Analysis:—	
Moisture	15.57%
Volatile matter	27.02%
"Fixed Carbon"	42.97%
Absolute Ash	14.44%
	100.00%

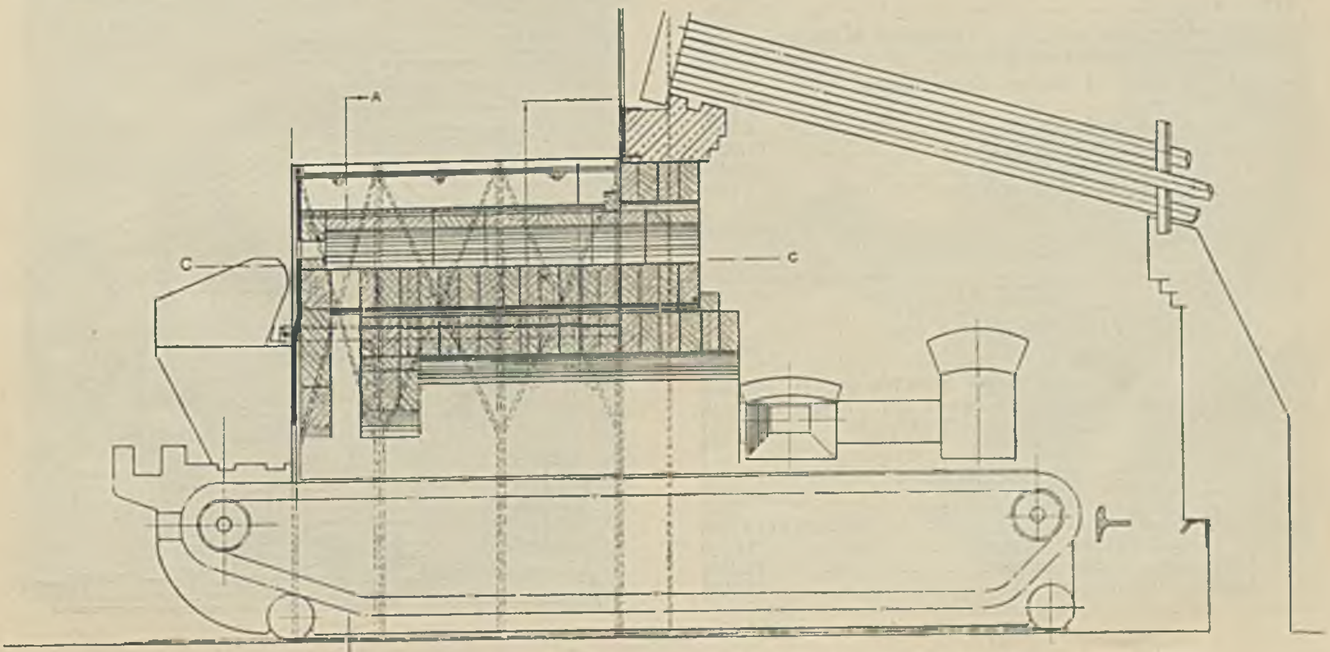


Fig. 3.—Chain Grate Stoker with setting for burning fuels exceptionally low in volatile matter.

Calorific Value as fired	9,638 B.Th.U.
Consumed per hour	1,001lbs.
Consumed per sq. ft. of grate area per hour	15.55lbs.

Riddlings.

Total Riddlings	335lbs.
Percentage of fuel fired	3.6%
Average hourly	36lbs.

Ash and Clinker.

Total weight	1,363lbs.
Percentage of fuel fired	14.6%
Proximate Analysis:—	
Combustible	16.0%
Absolute Ash	84.0%
	100.0%

Steam.

Average gauge pressure	92lbs.
Temperature of superheated steam	460° F.

Water.

Temperature of feed	156° F.
Hourly evaporation	6,119lbs.
Evaporation per lb. of fuel (overall figure, i.e., for 24 hours)	5.57lbs.
Evap. per lb. of fuel—running time on Laundry	6.32lbs.

Flue Gases.

Temperature leaving boiler	429° F.
Average CO_2 at boiler outlet	9.0%
Average O " "	8.5%
Average stokehold temperature	64° F.
Draught at boiler outlet	.3″ w.g.

Heat Account

(full day of 24 hours, i.e., including banking periods).

Thermal efficiency of Boiler, Superheater and Stoker	65.63%
Heat lost in ash and clinker	3.49%
" flue gases	13.06%
" moisture	5.54%
" radiation, recovering steaming position and heat in brickwork settings, &c.	12.28%
	100.00%

Heat Account.

(working day only, i.e., excluding night time when boiler is banked).

Thermal efficiency of Boiler, Superheater and Stoker	74.46%
Heat lost in ash and clinker	3.49%
" flue gases	13.06%
" moisture	5.54%
" radiation and unaccounted for	3.45%
	100.00%

TABLE VII.

Test with Fine Coal.

Plant.

One B. & W. W.I.F. type boiler of 5,160 sq. ft. heating surface, fitted with Superheater and Forced Draught Chain Grate Stoker, 8′ 0″ × 14′ 0″.

Summary of Results.

Fuel.

Name and Class	Wellington Gum
Size—Over ¼in. to ¼in. in size	5.03%
Over ⅛in. to ¼in. in size	45.28%
Under ⅛in. in size	49.69%
	100.00%
Analysis—Moisture	18.03%
Volatile matter	25.12%
"Fixed Carbon"	38.20%
Absolute ash	18.65%
	100.00%
Calorific value as fired (nett)	8,492 B.Th.U.
Consumed per hour	3,548lbs.
Consumed per sq. ft. of grate per hour	31.68lbs.

Steam.

Average gauge pressure	166lbs.
Temperature of saturated steam	374° F.
Temperature of superheated steam	615° F.

Water.

Temperature leaving economiser	152° F.
Average hourly evaporation	18,100lbs.
Evaporation per lb. of coal	5.1lbs.

Draught.

Suction draught at boiler damper	.5″ full
Air pressure under grate	.35″
Draught at fire door	Balanced
Suction draught in furnace	.15″

Flue Gases.

Temperature at uptake	580° F.
CO_2—Maximum	10%
Minimum	7%
Average	8.9%

Efficiency.

Boiler with Superheater and Stoker	72.58%

Low Caking Properties.

Coals of low caking properties, whilst of the nut or pea size, never presented any difficulties in burning but, on the contrary, were generally a very easy and satisfactory fuel to handle. With the falling away in size, difficulties were encountered but, with modern forced draught chain grate stokers and compartment control, these difficulties are very much reduced and such coals can be dealt with quite satisfactorily so long as the percentage of fines less than ⅛in. does not exceed, say 35%. In some cases, an even greater proportion can be dealt with.

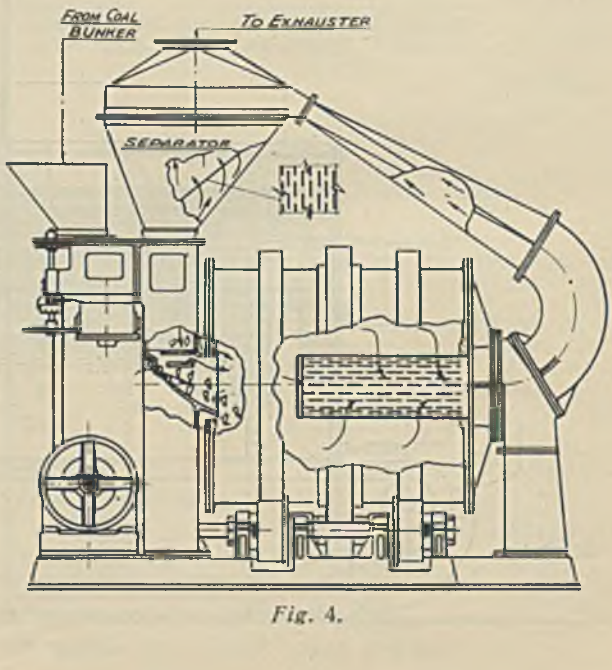


Fig. 4.

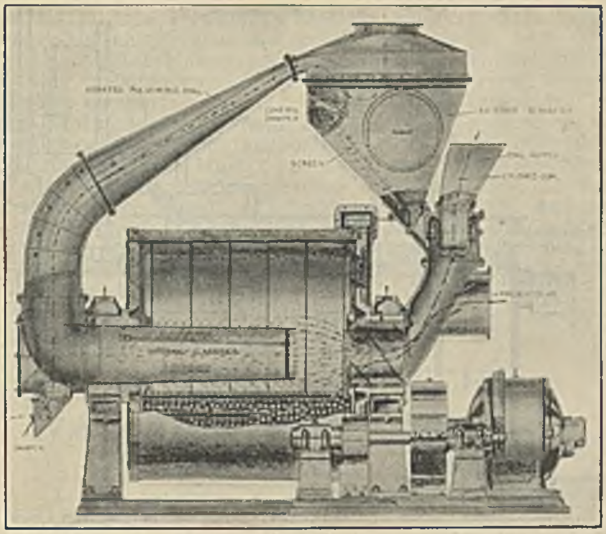


Fig. 5.

Very Hard Caking Properties.

A few English coals swell considerably on ignition and produce a very hard coke. Examples are some of the Somerset and Kent coals. With special furnace settings, however, these difficulties are overcome.

Deterioration due to Weathering over a Considerable Period.

The progress that has been made in the utilisation of low grade fuels is very clearly demonstrated by the numerous dumps about the country of fuel for which at one time there was no market, and many of which would to-day be considered quite a fair quality coal. In this district and in others, many of these dumps are providing the fuel for steam generating plant. Sometimes the coal is of such a quality that it can be burned even

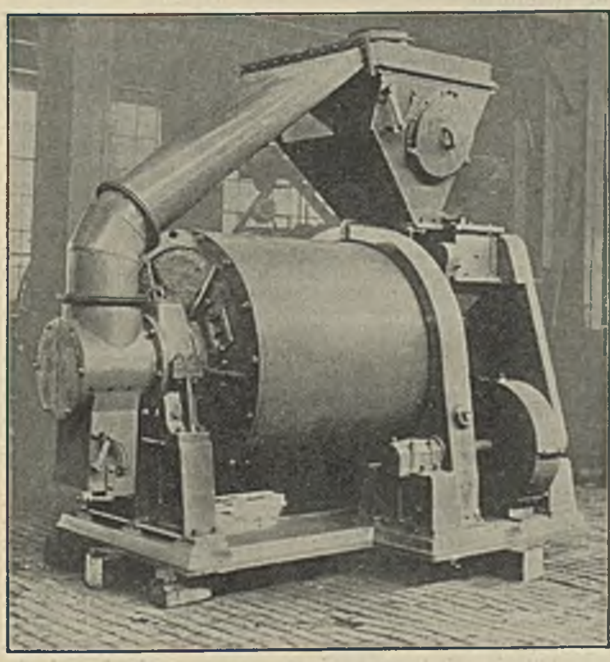


Fig. 6.

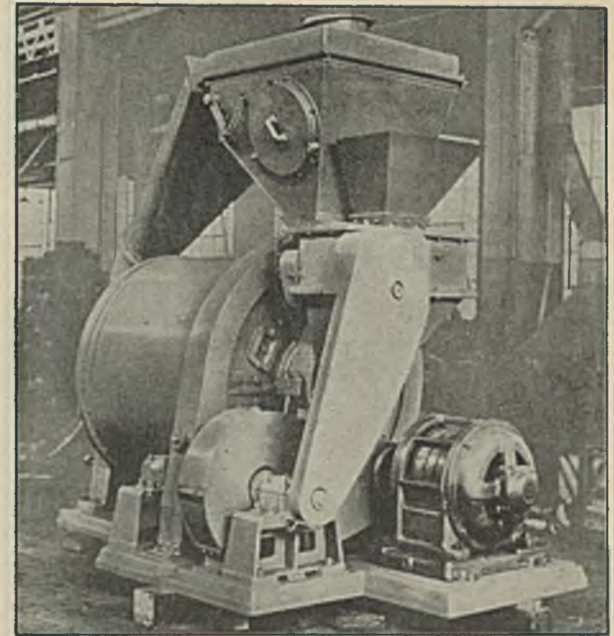


Fig. 7.

with suction draught only on a modern chain grate. Others are of lower quality and require forced draught and special brickwork setting. One interesting example is a power station in the North of England, where for several years past practically the whole of the fuel supplies have consisted of fuel from dumps, which are in some cases as much as 80 years old. The deterioration due to exposure to atmospheric conditions has been considerable, but the difficulties that this presented have been overcome and some of the coal burned, apart from its age, contains more than 50% of fines which will pass through ⅛in. mesh.

With regard to pulverised fuel firing, it is understood that the Association has only recently had a paper

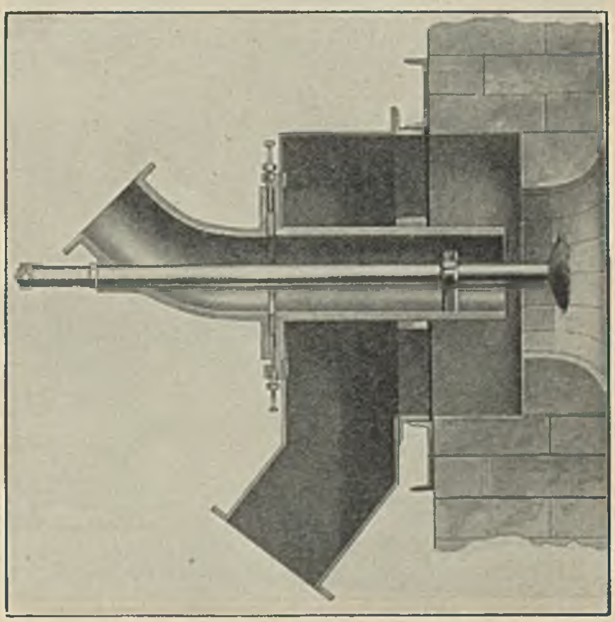


Fig. 8.

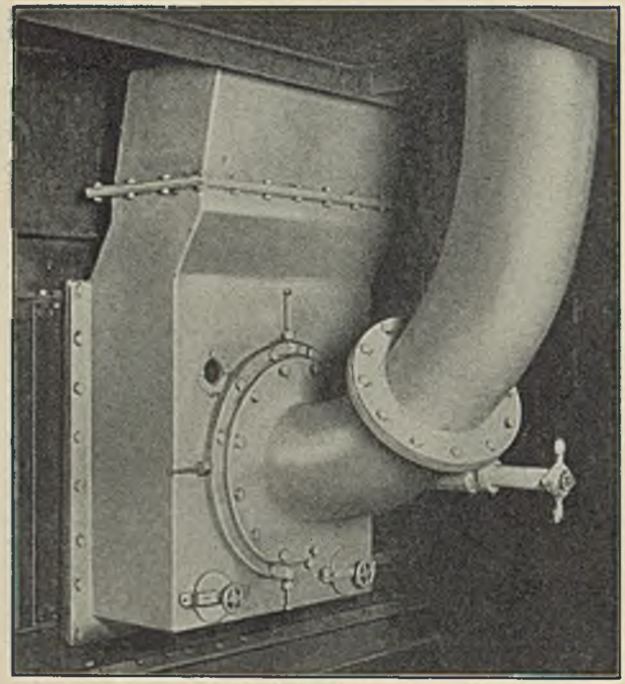


Fig. 9.

dealing with this subject and it is therefore not proposed to deal with it again at great length. Developments are constantly taking place in the design of pulverised fuel equipment, and these are in a great measure in the direction of simplifying the plant. Any of the classes of coal referred to above can be dealt with satisfactorily, and special designs of furnace are arranged to meet special requirements. The simplification of the plant is in the direction of direct firing after pulverising, and the employment of the dispersive type of burner.

Fig. 10.

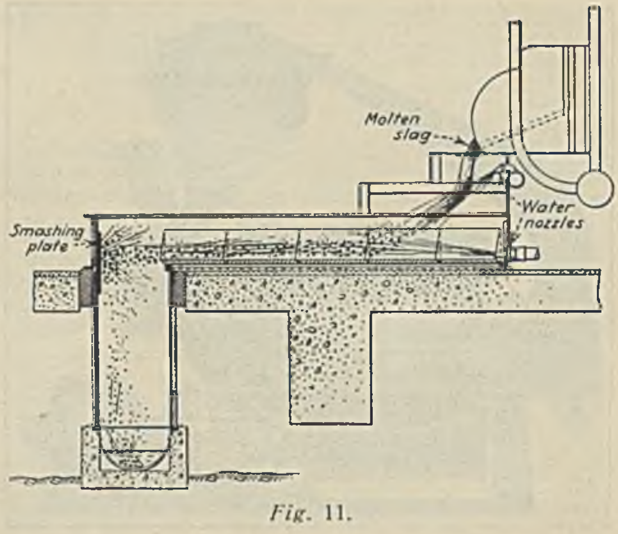


Fig. 11.

The illustrations Figs. 4, 5, 6 and 7 refer to a type of pulveriser which is now in regular use in a number of installations in this country. It is of the slow speed tube mill type. The particular advantages of this design are the small amount of wear and tear (which is practically confined to the balls and lining) and also the fact that wear does not affect the efficiency of pulverising. Further, the power consumption is low, being in the neighbourhood of 16 K.W.-hour per ton of coal milled. Separators are not necessary for removing any tramp iron that may be entrained with the raw coal, as this is merely retained in the mill. Moreover, dryers are not necessary with any normal coal as a considerable quantity of moisture can be dealt with in this type of mill provided the air supply is suitably heated.

The burner illustrated in Figs. 8, 9 and 10 has also now been in commercial use on several installations in this country for some time and has proved very efficient. The burner, without complications, is so designed that full control of the flame is obtained, it being possible to adjust the length as may be required to suit the fuel and conditions.

In the design of the furnace both for pulverised fuel and stokers special consideration needs to be given to the fusion temperature of the ash. A design of furnace wall construction recently introduced into this country is the Bailey wall. This construction consists of special blocks which are clamped to water tubes (connected to the boiler circulation), special attention being given to the jointing to ensure good contact between the tube and the block and, consequently, the maximum possible rate of heat transfer. These blocks are made of varying designs, some of cast iron only and others of cast iron faced with refractories. By this means it is possible to design the furnace in such a manner as to obtain the requisite furnace temperature to meet particular conditions, and the maintenance cost of the furnace is considerably reduced.

Where the fusion temperature of the ash is particularly low, it is sometimes considered desirable to employ the slag tap furnace bottom. In this case, as its name implies, the ash is drawn off in the form of a slag, in a similar manner to that employed for tapping a steel furnace. The illustration, Fig. 11, shows one of these furnaces being tapped.

As to the relative merits of stoker firing and pulverised fuel firing, this is a question which cannot be settled in general terms. A special consideration is necessary in every case, reviewing the whole of the conditions that apply to it. One of the few exceptions is when dealing with a dust fuel such as is produced by a dry coal cleaning plant. This is essentially a fuel for a pulverised fuel equipment. Slurry also is a possible fuel but, in that case, dryers are required and the handling of the fuel has to receive very special consideration as a result of which the plant is liable to be somewhat complicated and costly.

The subject covered is somewhat extensive and it is only possible to deal briefly with the several aspects of the question. It is, however, hoped that some of the information given will be of service to members of the Association from the point of view of the utilisation on the colliery boiler plant of the lowest possible grades of fuel produced, many of which have in the past been considered as wholly unusable refuse, and the colliery is naturally the first place at which such grades of fuel can be employed, owing to the absence of freight charges which are the same irrespective of the quality of the coal.

LOTHIANS BRANCH.

Visit to the Works and Laboratories of Scottish Oils, Ltd.

On the invitation of the directors of the Scottish Oils, Ltd., the members of the Lothians Branch of the Association of Mining Electrical Engineers visited the works and laboratories at Middleton Hall, Uphall, on February 23rd last. Nearly 100 members and friends availed themselves of the opportunity.

In the absence of Mr. Bryson, one of the directors, the members as they arrived were welcomed by Mr. G. A. McLennan, the company's chief electrical engineer, and the works manager, Mr. Twiggin. In small groups the party spent some two hours visiting the different workshops. It was a most interesting experience, and it was in the general-store more than anywhere else that one gained the best idea of the extent of the work that is done here. In most of the shops members of the staff had gladly given up their leisure to be present and to demonstrate the various machines. There were demonstrations of welding, this being in connection with the construction of the familiar green B.P. tanks; of an electric bolt heating machine, which brings a two inch bolt to a red heat in a few seconds; and in the joiners' shop of the last word in planing and other plant.

Naturally enough the electric fitting department excited the most attention. So much so that two groups of visitors indulged in a friendly argument as to the relative merits of the various kinds of machines. The testing boards for lighting sets were demonstrated, and the party moved along to see the motor repair shops where were several vehicles in various stages of overhauling. New chasses, which are soon to be on the road, in the familiar colour, were next viewed, and then the painting shops, where lorries and tanks were being re-conditioned. Here the beautiful enamel-like painted surface was much admired, and the guides found it difficult to convince the sceptical that it was done by hand and not by spray. The up-to-date garage, with its fleet of cars and lorries, its ambulance and fire engine, were not neglected.

The laboratories proved vastly interesting, and for more than two hours Mr. Guy, the chief chemist, and his chief assistants were kept busy explaining the equipment and answering questions. The fact that a good deal of the apparatus is electrical explains this desire for knowledge, which was readily gratified. The delicate and intricate machines for research in measuring candle power, distillation, etc., excited admiration. It was an educative two hours, and to the guides it must have been a pleasure to find the visitors so keen in their interest.

The inspection over, the members adjourned to the Parish Church Hall, where tea was served.

Mr. JAMES WALKER, President of the Branch, presided, and thanked the directors of the Scottish Oils, Ltd., for the invitation to view the works. It had been a most interesting afternoon and they were grateful to Mr. Bryson and the other directors. They had to thank also Mr. Twiggin, the works manager, who had arranged for members of his staff to be on duty, and Mr. Guy, the chief chemist. They were greatly indebted to those members of the staff who had given up their Saturday afternoon for the benefit of the visitors. He was always interested and glad to visit public works, and that afternoon there had been something to interest them all.

Mr. G. A. McLENNAN, a Past President of the Branch, in acknowledging the president's compliment said he could assure them on behalf of Mr. Bryson, who regretted he could not be with them, and the other directors and members of the staff that it was a real pleasure to have their company that afternoon. He thought this was the first meeting the Association had held in this district, and he was glad to see such a large turnout. He thought they might interpret that as meaning they should have one more often. While possibly they could not show as much as a large works such as Bruce Peebles, still he believed they were doing quite well a lot of useful work. They had been interested in the electrical winding shops. It would perhaps surprise them to know that the products of those shops went so far afield as Iceland and Persia. In the name and on behalf of Mr. Bryson and the other directors he had to welcome them, and personally he hoped they would enjoy what was to follow as well as they had enjoyed the first part of the programme.

When the tables had been cleared the Chairman said it would be absurd for him to introduce Mr. M'Lennan to them. They all knew him and his ability, and he was sure that the next half hour would be the reverse of dull. Mr. McLennan then read the following paper:

The Utilisation of Ultra-Violet Rays.

G. A. McLENNAN.

In bringing this subject before the A.M.E.E. the author is conscious that many members will be at a loss to understand why: but so certain is the importance of Ultra Violet Rays that the author makes no apology for placing these few facts before an electrical engineering society. It is not the intention to attempt, even briefly, to deal with the theory of Light, but to confine these notes to the practical applications of Ultra Violet Rays in the hope that they may teach something of the remarkable results that have been obtained, both in the theurapeutic and technical use of this comparatively new science. The subject may be approached under four heads:—

(1) Historical,
(2) Types of lamps,
(3) Medical, technical and industrial uses of Ultra Violet Rays,
(4) Industrial welfare applications.

Historical.

Though treatment by artificial sunlight is a development of only the last few years, the curative value of natural sun rays was fully realised by the ancients. The Romans exploited their uses very freely. It is an interesting fact that to bathe in pure air and sunlight is the literal meaning of the Greek word "gymnastics." The ancient Greeks and Romans commonly practised sun-bathing as a routine in their daily life, and Homer's beautiful word-picture of the Trojan maidens combing their hair in the sunlight is descriptive of what was common in the ancient world.

In the middle ages the value of sunlight was again realised sufficiently to cause people to isolate, and expose to the natural curative influences of the sun and air, those who had been contacts in plague-stricken areas and ships.

It was in 1893 that Professor Finsen published his work upon the remedial action of sunlight and, through the interest taken by the late Queen Alexandria in her countryman Finsen and her zeal for the relief of suffering, the London Hospital acquired a Finsen installation. Beyond its utility in the cure of Lupus, the medical world did not seem fully to appreciate or exploit the possibilities of "sunlight" treatment until the present century opened.

In the year 1903 Dr. Rollier began to expose patients to the cold mountain sunshine at Leysin, on the borders of French Switzerland. Most people smiled and said the patients would die; but they did not die. What was more to the point, they were cured. Modern science has emphatically confirmed the teaching of age long experience, and we must now become familiar with the wonders of health and healing, and the success of technical and industrial applications achieved by sunlight, whether natural or artificial.

Types of Lamps.

The question whether artificial sunlight is as valuable as natural sunlight in the treatment of disease has given rise to much discussion, but Dr. Rollier, who is regarded as the greatest authority on natural sunlight treatment, is quoted as saying: "Sun and Ultra Violet Rays bear much the same relation to one another as crude drugs to their synthetically prepared chemical substitutes." The consensus of opinion seems to favour the view that Ultra Violet Radiation is equal, if not superior, to natural sunlight. Modern science has now made artificial sunlight available through the use of various types of sunlight lamps.

These lamps may be divided into two distinct types: The Open Arc and the Mercury Vapour Arc. Both are made in several patterns, and the different types of lamps give rays in varying degree. The quality of radiation of arc lamps depends upon the nature of the electrodes used, and of these there are three distinct types: Tungsten Rod, Carbons cored with various salts and metals, and Carbons. The value and intensity of the ultra violet rays given out by these three types of electrodes are in the order given. The Tungsten Arc is only suitable for direct current. Probably the most generally useful, and certainly the most powerful type of lamp, is the Mercury Vapour Arc, and this is capable of being used on either direct or alternating current. In this type of lamp a current of electricity is passed through the vapour of molten mercury contained in a quartz tube, and electrons in the form of ultra violet energy are driven off similarly to X-rays. The quartz tube allows all the rays to pass and also withstands the heat. It should be remembered that ultra violet rays are quite invisible to the human eye.

Medical, Technical and Industrial Applications.

The growth of industry during the last century, with its consequent congregation of masses of people in towns where fresh air and sunlight penetrate only with difficulty, and in which the pall of factory and house smoke has played such an evil part, has caused the need for the restoration of sunlight to be increasingly recognised. What Dr. C. W. Saleeby, Chairman of the Sunlight League, has called "Diseases of Darkness," have developed in this vicious atmosphere; tuberculosis and rickets are outstanding examples. The importance of sunlight may be more readily understood when it is known that the germs of tuberculosis live and remain virulent after two years in the dark. Pure sunlight kills them in from seven to ten minutes. Sunlight is nature's finest antiseptic. It increases resistance to disease, and even when disease has got a hold it helps greatly to overcome it. Constitutionally, such troubles as rickets and tuberculosis stand out so pre-eminently as to dwarf other utilities, but anæmia, congestion, etc., are a natural field for sunlight.

One remarkable property of the ultra violet rays is that they are readily capable of absorption by the blood circulating in the tiny vessels of the skin; they also bring about great changes in the metabolism of the body, the beneficial effects of this being carried into the general circulation and distributed throughout the system. The colouring matter of the blood can actually be increased by their action in cases of such diseases as anæmia and rickets.

As might be expected, its dermatological uses are manifold. Eczema, Lupus, Ringworm, Psoriasis and Ulcers are but a few of the skin disorders which clear up under ultra violet rays more readily than by any other means.

Ultra Violet Rays is a most potent bactericidal and germicidal agent, and to this it owes much of its value. Too much emphasis can hardly be laid upon these effects, for they operate either as primary or secondary manifestations in an enormous proportion of the cases met with in daily practice. Many of the cases cannot adequately be reached by the usual germicidal and bactericidal agents; consequently the field for ultra violet rays is immense, and much too extensive to be dealt with here in detail. Wherever toxins exist, or infection has taken hold, irradiation can be used to stultify and neutralise it.

Varicose veins, hay fever, pyorrhœa, in all of which very great success has been recorded, merely serve by their differences of origin and incidence to show how very wide is the field in which sunlight exhibits its powers; a logical development following upon the therapeutic value of ultra violet rays to human health in its adaptation for use on plants and animals. In the propagation of growth and the maintenance of health, many experiments have been made and the results obtained are very satisfactory. The use of the rays in poultry farming is a noteworthy example of this, the birds treated being more healthy and the egg production being very considerably increased.

The Mercury Vapour Lamp is to be found in most up-to-date laboratories, and the technical uses to which it is put include the testing for fastness of dyes, inks and colours, the stability of paints, varnishes, celluloid and rubber, and the separation of metal ores, tailings and finings. Proof of the genuineness of precious stones, pearls, documents, banknotes, paintings and antiques has been made possible by the discovery of filters passing only ultra violet radiation. One of the most interesting discoveries with invisible light is fluorescence, and it has now been proved that many substances show a fluorescence under ultra violet rays, and that the otherwise unknown can be determined by comparison with the known.

The Analytic Quartz Lamp is designed for the radiation of substances with invisible ultra violet rays only, and is provided with filters which pass much of the ultra violet and exclude most of the visible. The burner is enclosed in a light tight chamber at the top of the apparatus, and provision is made for the utilisation of both vertical and horizontal radiations. The filters are removable so that the full unfiltered radiations may be utilised at will. When the rays strike a substance capable of fluorescing, the short wave lengths are changed into visible light of longer wave length, and the curious glow is seen which is known as fluorescence. By noting the colour variations, it is possible to identify like substances with absolute accuracy in many instances. This method has already had numerous practical results which are extremely interesting.

Scotland Yard and many banks, both in this country and abroad, are using this apparatus in the detection of palimpsests and alterations to documents. Counterfeit bank notes and suspected documents are examined beneath the rays, and frauds are immediately detected due to the inks used in the falsifications fluorescing differently from the original text, and also from the parchment or paper itself. In cases of arsenical poisoning, the presence of the drug can be found, no matter by what foreign substance it may be surrounded. Diamonds glow like beautiful blue lamps under ultra violet rays, but imitations are quite lifeless and dull. The testing of dyes and colours is also an important development of ultra violet rays, and a lamp has been designed and is now in use which tests the stability of all materials likely to undergo change in sunlight. In this lamp the quartz burner is suspended at the axis of an aluminium drum two feet in diameter, provision being made for the fastening of the samples to the internal circumferential surface.

From a number of tests it has been computed that this apparatus has a value of about eight times that of sunlight, or roughly, one hour's radiation is equal to one full day's exposure to the summer sun. The patent leather industry has seen the substitution of quartz mercury vapour lamps for the sun itself. In one factory on the Continent alone, more than 1,500 lamps are in daily use. Processes have been patented for the manufacture of sulphuric acid using ultra violet radiations; the radiation of foods for vitamin activation; and the drying, bleaching and deodorising of various oils and fats. The radiation of foods is being very rapidly developed. When various foods are irradiated, the vitamin content is increased, consequently increasing the food value. For some time past the milk used in hospitals and sanatoria has been irradiated, thus producing complete sterilisation and also increasing the calcium content, and now means have been devised for the mass production of irradiated dried milk. Butter is sterilised by being put on an endless band passing before a lamp, and though there is a slight change in chemical composition, there is but little difference in colour.

Many bakeries are now treating their dough with ultra violet rays, the effect being to increase the vitamin content in addition to making a healthier loaf, brighter in colour, silkier in texture and richer in flavour. The Bermaline Bread Factory has adopted this treatment with good results.

Welfare Application.

Much is heard to-day of the efforts to improve the general condition of our industrial population by the provision of Institutes, Baths, Clubs, Playing Fields, etc., but there is probably nothing in industrial welfare to-day to compare with the marvellous results obtained by the installation and application of ultra violet ray apparatus in factory and walfare clinics. The facts were prominently in the minds of some medical and lay workers. These workers were brought together under the auspices of the New Health Society; and a committee, consisting of both medical and lay men, the authors of a report entitled "Artificial Sunlight in Industrial Hygiene," was set up for the purpose of conducting a demonstration.

The Sherwood Colliery Clinic.

It was decided that the Mining Industry should be selected for the purpose of this demonstration, and Major J. B. Paget who, as early as June, 1924, had suggested light baths for miners, was asked whether it could be conducted at the colliery of which he is a director. Arrangements were made for the erection and equipment of a light clinic at the Sherwood Colliery pithead, and so began a demonstration which has proved, without any doubt, the wonderful health giving properties of ultra violet rays.

In order to interest the mining population in Mansfield in regard to the proposal, and especially the colliery workers at Sherwood; moreover, to engage also the interest of the public and of the press in the project, five pit boys were selected at random by Lieut.-Col. G. S. Hutchison, a member of the committee, for a tour in Switzerland. Those selected consisted of two pony boys and one trammer working below surface, and two younger boys working on the screens. The ages of the boys selected were two of 13 years, and one each 14, 16 and 17 years respectively. They were taken to a private chalet at Griesalp in the Kiental, Switzerland, and were there for seventeen days. The treatment given followed the general principles of Dr. Rollier at Leysin. It was not to be supposed that any physical developments and other manifestations of better health would be due alone to exposure to the actinic rays of the sun. Other factors contributed to the results obtained. The results of this experiment in Switzerland are detailed in the report mentioned; the results were quite remarkable and not by any means least among the lads' own parents and families and fellow workers at Sherwood Colliery.

The success of this demonstration at once aroused the keenest interest amongst both the management and the colliers in the forthcoming clinical demonstration. A large clinic of bungalow type was equipped by the generosity of the Directors of the Colliery. The baths of light proceed from six large mercury vapour lamps. These lamps were aided by four heat producing Sollux lamps.

One hundred lads were selected for the demonstration, and the results may be summarised briefly as follows: The average nett gain in weight, per boy treated, was nearly double that of the average gain in those not treated. Similarly it was shown that the average increase in height amongst the treatment group was 50% over those not treated. The general appearance of the boys in the treatment group improved considerably. The report states that a marked air of brightness and cheerfulness was noticeable as compared with those not treated. Nearly all the boys in the treatment group state that their appetite had improved and their work seemed easier."

Although the clinic was opened for the purpose of the demonstration, two other classes of persons have attended the clinic, the first being adult miners, and the second being children. The total number of treatments given in about three months was 6,554. Towards the end of three months, about 500 patients were attending the clinic, and the plant was taxed to its utmost capacity. As many as eighteen local medical practitioners sent their patients to the clinic for treatment. The report on this installation concludes as follows:—

"(1) In view of the realisation of the importance of such clinical treatment by the Medical Profession, as is shown by the large number of private practitioners already using artificial sunlight lamps and the fact that many hospitals are so equipped, the Committee recommends that, in the interests of national health, such clinics be developed with all possible speed."

"(2) In view of the fact, as has been demonstrated at Sherwood, but also in all similar clinical practice, that certain specific diseases to which we, as a nation, are especially subject, namely, rickets, rheumatic affections, skin diseases, and surgical tuberculosis, can be greatly relieved by such clinical treatment, and as is clearly established from official statistics that these diseases are the cause of much absenteeism in industry, the Committee recommends the urgent consideration of such clinical treatment as part of the national health programme by those who have the authority to facilitate such projects."

"(3) The Committee is satisfied that such clinical treatment is of real value to the mining industry, having regard to the health and psychology of the worker and the relations between him and the Management. It is established from this demonstration also that the installation of such a clinic is a matter of quite small cost, and such clinics could be readily installed at the pithead or the factory gate."

"(4) The Committee recommends that wherever pit-head baths are being installed, light baths should be associated with them. The Committee recommends also, in view of the alleviation which such treatment can give to miners suffering from rheumatism, arthritis, lumbago, and the after effects of pit accidents, that whether or not pit-head water baths are installed, such a light clinic be available to those workers who, as the result of the incidence of their employment, have received injury from which they can by this means be conveniently relieved."

Other Clinics.

It is gratifying to know that there are hundreds of firms in this country, and in Europe and America, who have installed artificial sunlight welfare installations, and installations in their Works' First-aid Clinics. In close relation to the Welfare Clinics are the clinics provided by the Corporations of Leeds, Bradford and Edinburgh. In each of these cases, success has attended the provision of these facilities for treatment. The Edinburgh installation, which was planned by the Medical Officer of Health, consists of Open Arc and Mercury Vapour Arcs, and was installed in order to provide facilities for those who could not afford to pay the somewhat prohibitive fees that were being charged by privately run concerns. From the opening day of this Sun Ray Centre at Portobello Baths, the scheme has proved a success. Medical men are freely taking advantage of the Centre by recommending patients to go there. The attendances have been: November, 394 males and 358 females; December, 399 males and 412 females; January, 437 males

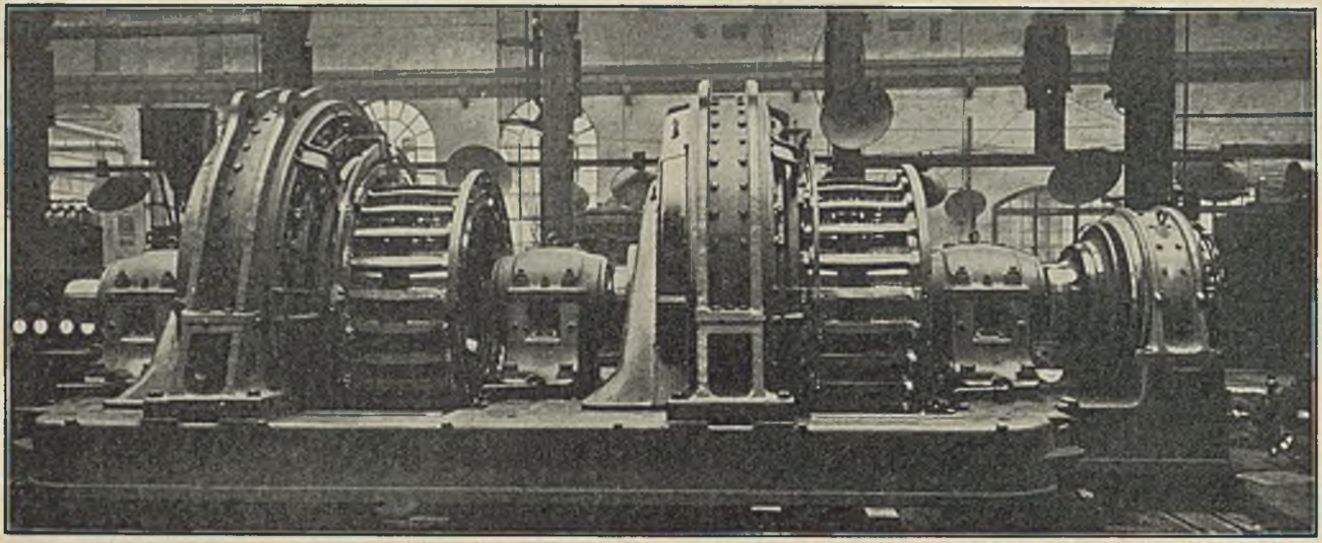


Fig. 1.—One of Ten Tandem Units, 6000 *K.W.,* 600 *volts,* 200 *r.p.m., for coupling to English Electric Co. Water Turbines for the British Aluminium Company.*

and 446 females; a total during the three months of 1230 males and 1216 females.

Those suffering from Anæmia, Nervousness, Rheumatism, Sciatica and General Debility have been the chief applicants for treatment. Skin diseases and Tuberculosis are not dealt with at the Portobello Baths, because provisions are made at other Institutions for such diseases.

Dr. L. C. Donnelly, M.D., Detroit, says: "To the employer of labour, Ultra Violet, when he has used it, has proved a godsend. It is the most powerful germicide in existence that kills germs without injuring the tissue cells."

Dr. George, of the Packard Motor Car Co., stated that he believed that the use of Ultra Violet in their plant had reduced the amount of amputated fingers about 80 per cent., and that it reduced the disability at least forty per cent.

Of even greater use than the local sterilising, pain relieving action of ultra violet energy is the effect of general treatments which develop the man's morale by building up the resistance of every cell. Ultra violet energy is the greatest tonic.

A short time ago the General Electric Co. of America made some very extensive investigations regarding the effect of Ultra Violet Light on the efficiency of employees. In the course of a month's time, it was noted that the employees under the ultra violet lights were producing considerably more work, and that the percentage of errors was greatly reduced, and also that the number of hours lost by sickness had been greatly reduced.

Before exhibiting the film "Sunlight is Life" the author would like to take this opportunity of drawing attention to the loss of opportunity manifested in the pit-head baths installed last November at the Dalzell and Broomside Colliery, Motherwell. It was difficult to understand how the Miners' Centre Welfare Committee could, in view of present-day knowledge, go forward with any welfare scheme without an ultra violet ray installation.

(The author here demonstrated with the film "Sunlight is Life," and acknowledged his indebtedness to The British Hanovia Lamp Co., to Ajax, Ltd., and to Mr. Robert Gracie who had rendered him considerable assistance; also to William Robertson, Esq., Medical Officer of Health, Edinburgh, for particulars of the Portobello Baths Sun Ray Centre).

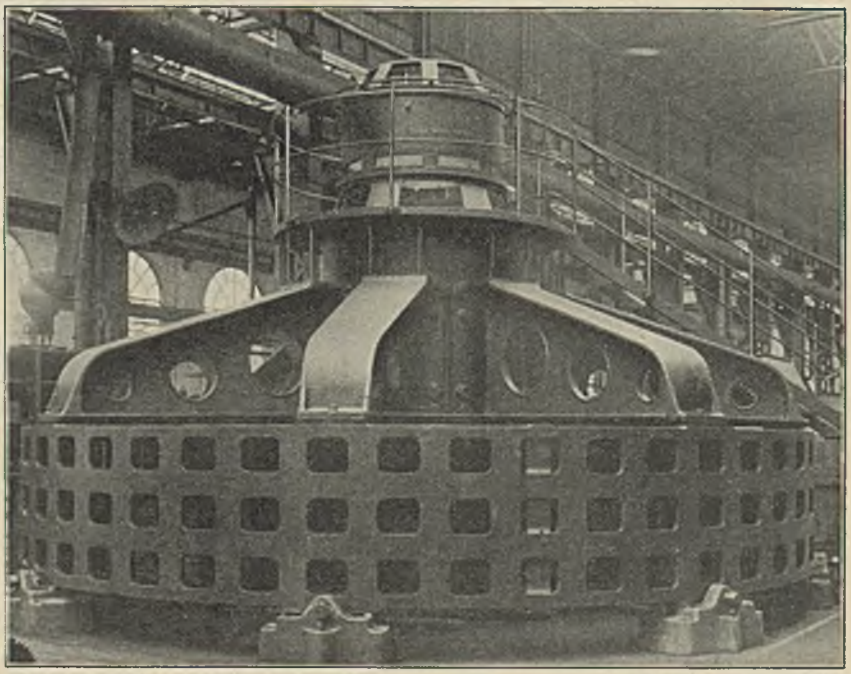


Fig. 2.—An English Electric 11,250 *K.V.A.,* 6600 *volts,* 94 *r.p.m. Alternator for coupling to Vertical Water Turbine.*

NORTH WESTERN BRANCH.

Visit to The English Electric Co.'s Works, Stafford.

A large party visited the works of the English Electric Co. at Stafford on June 29th. The majority of the members were from the Wigan district and made the journey from Manchester and Wigan by road. The members owning private cars provided the transport for the members who had not this means of locomotion at their disposal. The journey was thus made with the greatest of comfort to all concerned and added much to the enjoyment of the visit. The party was met at the works by the Branch President, Captain I. Mackintosh, and were then detailed into small parties under the leadership of members of the English Electric Co.'s staff who conducted the various parties around the works.

Among the items of interest seen were a 37,500 K.V.A. 3,000 r.p.m. turbo alternator for the West Ham Corporation, a number of 3,000 K.W. direct coupled water turbo driven generators, rotary converters, motor converters and induction motors of various sizes destined for all parts of the world.

A 15,000 K.V.A., 132,000 volt transformer for the Scottish Grid Scheme aroused considerable interest among the members. The detail of transformer construction was minutely described. This transformer is delta-star connected and has low-voltage windings arranged for series (22,000 volt) or parallel (11,000 volt), with cooling to give 75% of full load with natural cooling and full-load with artificial cooling. Artificial cooling is obtained by means of a fan motor. The illustration, Fig. 5, shows the completely assembled transformer with on-load tap changing gear mounted on the tank side and the necessary small auto-transformers underneath as used in conjunction with the on-load switchgear.

The parties then proceeded into the Switchgear Bays where they saw draw-out types of E.H.T. gear, E.H.T. draw-out truck cubicles, switchboards of various types, unit pillars for industrial and mining work; also automatic control gear for rotary converter substations which appeared almost human in precision and probably more reliable in carrying out the various functions.

Another very interesting item and which certainly appealed to all present was an 11,000 K.V.A. slow speed alternator to be driven by a vertical spindle water turbine. Induction regulators of various sizes were also

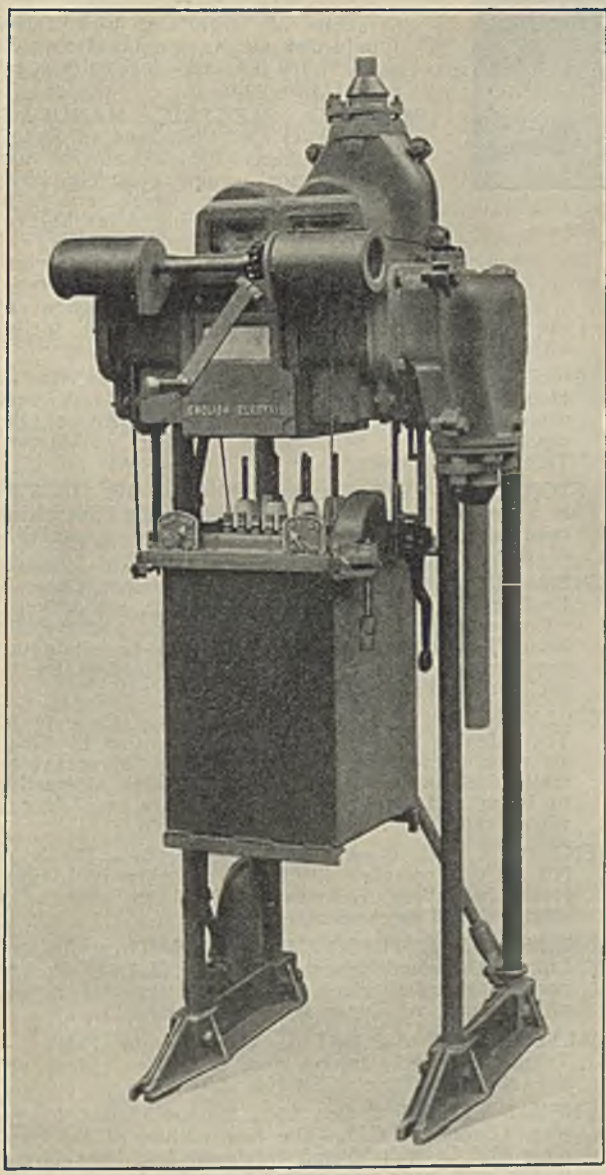


Fig. 3.—A 3300 volt, 200 amp., Three-phase Flame-proof Switch Pillar (English Electric Co.).

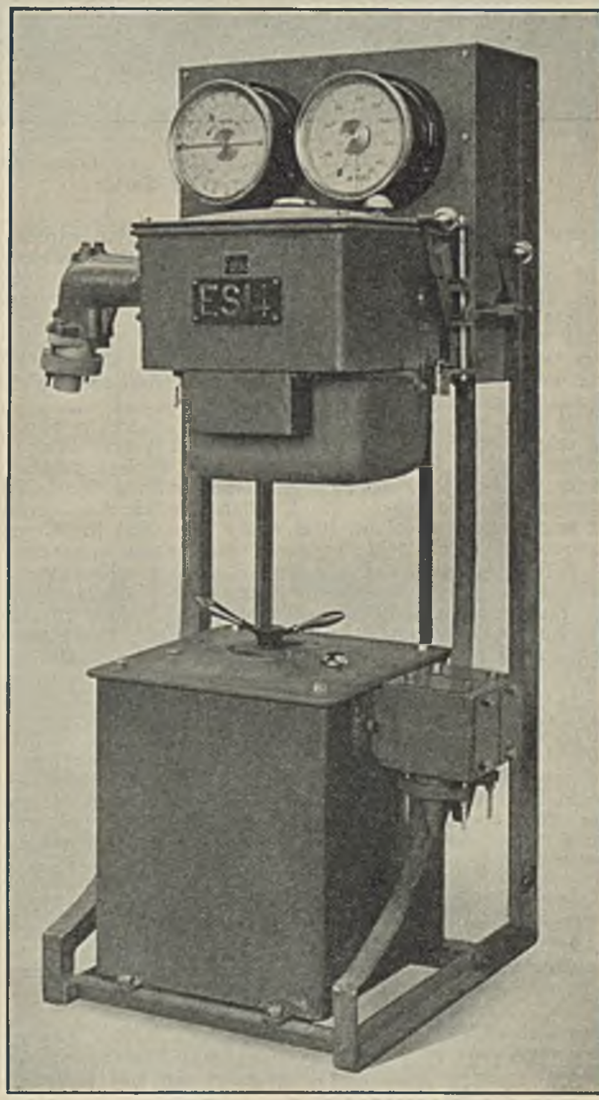


Fig. 4.—Motor Starting Pillar with Oil-immersed Switch and Rotor Starter.

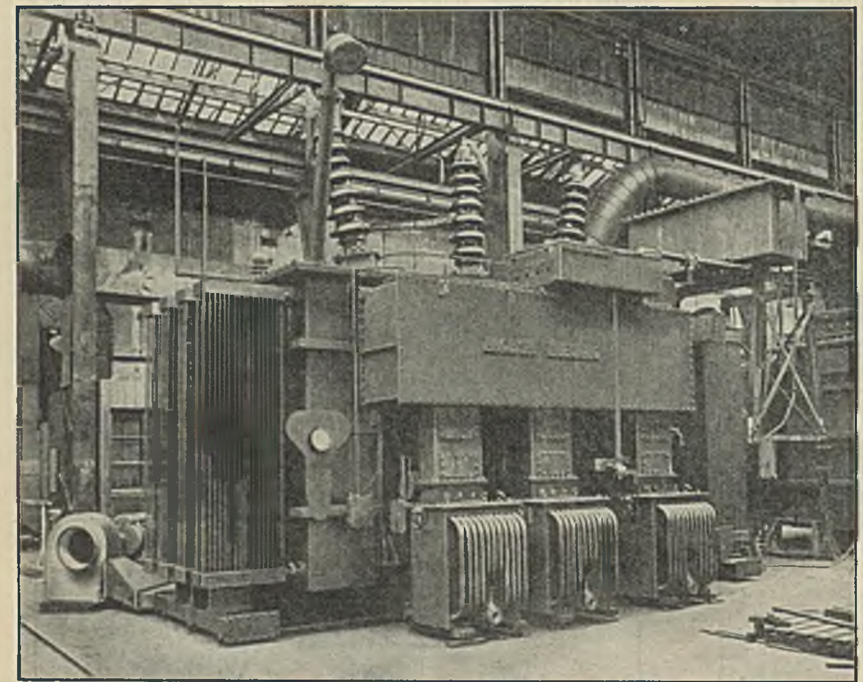


Fig. 5.—A 15,000 K.V.A. 132,000 volt Transformer for the Scottish Grid System.

closely inspected. Many members were heard to express the opinion that it was quite evident that the greatest care in detail was taken during the manufacturing process, showing that no expense was spared in turning out really first class and robust jobs; points which certainly appeal to members who well realise that in colliery work these details are essential if the plant is to give satisfaction under the very severe conditions which mining machinery has to withstand.

It was regretted that time was too short to allow the whole of the works to be seen; as it was several sections had to be passed with a more or less cursory glance. When it is realised that the Stafford Works is only one of five where the English Electric Co. carry out manufacture of plant, it is easily seen that the Company covers a very wide range of engineering apparatus.

After inspection of the works the members were taken to the Company's Guest House, the "Old Hough," and there entertained to tea. A vote of thanks to the Company was proposed by Mr. A. M. Bell, the immediate Past President of the Branch, who said that on behalf of the Branch he wished to thank the English Electric Co. for granting them permission to visit their Stafford Works and also for their hospitality. They now had seen many examples of Stafford products which showed the highest standard of design, material and workmanship. The presence of Captain Mackintosh on the Staff of the English Electric Co. would help to ensure that the mining types of apparatus turned out would fully comply with all requirements and would further extend the use of English Electric products for collieries.

Mr. G. Bell having seconded the motion, Mr. H. S. Carnegie suitably replied on behalf of the Company.

NEW CATALOGUES.

VACUUM OIL Co., Ltd., Caxton House, Westminster, S.W. 1.—The new edition of the Company's technical book No. 24 deals with the principle of operation, care, and maintenance of steam turbines and their accessories.

BRITISH THOMSON-HOUSTON Co., Ltd., Rugby.—The new index of B.T.H. publications is a useful classified guide to the many technical catalogues and lists which serve to cover the B.T.H. range of products.

New B.T.H. catalogues deal respectively with Starting Rheostats, Thermal Circuit-Breakers, S.C. Induction Motors, Air Filters, Auto-Transformer Starters, Rotary Converters, Air Cooling Systems.

FERRANTI Ltd., Hollinwood, Lancs.—This Company has recently issued about a dozen illustrated price sheets concerning their latest designs in radio apparatus and details.

METROPOLITAN VICKERS ELECTRICAL Co., Ltd., Trafford Park, Manchester.—Descriptive Leaflets No. 40/1-1 and 40/2-1 are valuable technical publications showing the construction, performances, and ratings of large and high speed induction motors ranging from 100 to 11,000 h.p. and for voltage up to 11,000 volts.

MIDLAND ELECTRIC MANUFACTURING Co., Ltd., Barford Street, Birmingham.—This Company has just issued a new complete illustrated catalogue which not only gives full particulars of the M.E.M. products but gives particulars of the designs and the installation of electrical switch and fuse gear.

A new utility switch is a recent development of the M.E.M. range. Particulars are given in an attractive coloured folder.

TUNGSTONE ACCUMULATOR Co., Ltd., 3 St. Bride's House, Salisbury Square, London, E.C. 4.—A very complete illustrated catalogue gives details of the construction and performance of the well-known Tungstone Batteries.

J. STONE & Co., Ltd., Deptford, London, S.E. 14.—This is a well produced catalogue of valuable information concerning the H-R Gears which are a speciality of this Company.

BRITISH INSULATED CABLES, Ltd., Prescot, Lancs.—Leaflets give general details concerning, respectively, "Copperweld" for over-head line work, and "Rockbestos" products. Other more complete catalogues are devoted to Prescot Meters and Helsby ebonite enclosed wiring system.

ROWLAND HILL & SONS, Ltd., King Street, Coventry.—The valuable little booklet directs attention to Alpax an aluminium-silicon alloy, possessing advantageous mechanical properties. It is offered as an alternative to brass and iron for many machines and fittings where resistance to corrosion is sought.

GENT & Co., Ltd., Faraday Works, Leicester.—The book No. 6b is a complete illustrated price list of Liquid-level, indicating, recording and alarm signals of electrical and mechanical types.

TUNGSRAM ELECTRIC LAMP WORKS (Great Britain) Ltd., 72 Oxford Street, London, W. 1.—A handy pocket price list gives ratings and general details of the range of Tungsram Pearl Lamps.

WALTER McGEE & SON Ltd., Albion Works, Paisley.—Totally enclosed squirrel cage induction motors are the subject of the new list No. 200.

GENERAL ELECTRIC Co., Ltd., Magnet House, Kingsway, London, W.C. 2.—The new edition of the complete G.E.C. switchboard catalogue has been issued in the customary substantial form fitted with attachment clips for inclusion in the G.E.C. main volume of catalogues.

Manufacturers' Specialities.

The North-East Coast Exhibition.

(*Continued from page* 116).

BABCOCK & WILCOX, Ltd.

Two scale models served to exhibit the main characteristics of Babcock boilers: one represented a cross type marine boiler complete with interdeck superheater, superposed counter-flow economiser, and tubular air heater, the furnace being fitted with the latest type of Babcock mechanical chain grate stoker; the other model represented a marine type Babcock boiler as commonly installed in the mercantile marine and fitted for the burning of oil fuel.

The Company also show a complete model illustrating The Babcock Process of Low Temperature Coal Distillation with the recovery of tar oils; this plant included low temperature retorts supplying pulverised semi-coke to the furnace of a Babcock pulverised fuel boiler or, alternatively, supplying semi-coke in lump form to the chain grate of a stoker-fired boiler.

Another model shows the firm's balanced lever luffing crane as used for coal unloading, general cargo discharge and similar purposes.

The heaviest feature of the exhibit consisted of a complete totally-enclosed single gear 7in. by 12in. steam winch. This plant was shown in operation; the winch was arranged for a lifting load of one ton and, for the purposes of exhibition, was fed by compressed air supplied from a Bellis & Morcom electrically driven two stage compressor.

A representative selection of pipework of Babcock's manufacture, consisting of expansion bends, straight runs, and connections were shown. Parts of the pipework were lagged and available for examination: there were two lines, one delivering air to the winch and the other serving as the exhaust.

Other Babcock exhibits included a selection of Victory wrought steel valves, which the Company manufacture under license, and a selection of Babcock parallel slide and other valves for all purposes: there were also sections of interlock steel flooring for boiler galleries, engine room floors and similar purposes, a calorised "Diamond" soot blower head, and an example of illuminated water gauge fittings.

Exhibit of Babcock & Wilcox, Ltd.

THE CONSETT IRON Co., Ltd.

Though it is one of the oldest established iron and steel manufacturing firms in the United Kingdom, this Company prides itself on its progressive policy, and by its recent extensive reconstruction schemes it now has probably the most up-to-date steel plant in Great Britain. In addition to all classes of steel plates, sections, and joists for ship-building, bridge building, boiler-making, etc., the Company's products include gas, steam and coking coal, bee-hive and patent oven coke for furnace and foundry purposes; hematite and foundry pig iron; high grade silica materials for furnaces, coke ovens and gas retort constructions, as well as blooms, billets, etc., for drop stamping, wire drawing purposes and so on.

Exhibit of The Consett Iron Co., Ltd.

The Consett Stand was impressively dignified in design, being composed of steel joists and channels rolled at the Company's works, and the flooring of Consett steel chequer plates.

Silica shapes and retort sections were ingeniously used in the construction of the office which occupied the centre of the Stand, and flanking the office were two complete coke oven sections as used in the construction of modern coke ovens. The whole of the bricks, steel castings, and buckstays were manufactured at the Company's works at Consett.

The exhibited specimens included springs, forgings, drop-stampings, etc., made from Consett steel; high tensile wire drawn from Consett acid steel billets; and a large case of various rolled sections. Other exhibits included fractures of hematite and foundry pig iron, and specimens of coal and coke for furnace and foundry purposes.

One end of the Stand was devoted to the display of steel for colliery purposes, including steel arches, with special fishplates to give the maximum amount of support at the crown of the arch; steel crowntree roof supports; and steel colliery rails. The arches as shown are of mild steel and ranged in section from 6in. by 5in. joists to 4in. by 2½in.

The Consett Company had also a second Stand where a striking demonstration was given of the use of Consett coke nuts, a smokeless fuel, burning in open fireplaces.

DAVIDSON & Co., Ltd.

The well known "Sirocco" range of fans was shown in a diverse and most attractive form on the stand of Messrs. Davidson & Co., Ltd., Belfast. This firm claims that it lists as standard no less than 1,200 different sizes and types of the "Sirocco" fans which are used for every purpose for which a fan can be employed. There were exhibited fans for Ventilation; for Dust Removal; for supplying blast to Forge Fires, Furnaces or Cupolas; fans for furnishing large volumes of air or alternatively for setting up high pressures.

A scale model was introduced to represent the "Sirocco" mine fan, of which there are many in operation in all parts of the world, while an interesting exhibit of this particular application was the large fan blade identical with those on one of the most powerful mine fans in the world. This particular fan is at work on a South African colliery, and is driven by a 1,200 H.P. engine.

For dealing with corrosive gases, the fan protected internally by vulcanite presented obvious advantages.

A spectacular and fascinating feature of the exhibit was the "Sirocco" Aerostat. Here were ten balls circling in jets of air around the top of a pillar. The "Sirocco" Aerostat was not only attractive to the eye, but presented to those who seek the why and wherefore of things a puzzling problem as to why the balls were not blown away. It was a clever and attractive demonstration of one of the curious phenomena of aerology, and the source of much popular interest and speculation.

C. A. PARSONS & Co., Ltd.

Turbo-Sets.

The principal piece on one of the most imposing stands was a Parsons 3000 r.p.m. reaction turbine designed for working with steam at 165lbs. per square inch absolute and a temperature of 466 deg. Fahr. The governor, tachometer and oil pumps are driven by a worm gear at the end of the turbine shaft. The worm drives a horizontal cross shaft, at one end of which is the governor, and at the other a pair of bevel wheels driving a vertical shaft for the tachometer and oil pumps. An overload valve is fitted on the top of the turbine cylinder and it is operated by the same mechanism that controls the regulating valve. When the latter valve is opened sufficiently to maintain the full load output of 5000 K.W. at the speed of 3000 r.p.m. at the designed pressure, any further advance causes the valve spindle to act on the overload valve in the upper part of the turbine casing by means of a system of levers. This overload valve is thus lifted from its seat, and high pressure steam is then allowed to pass from the inlet annulus of the turbine to a second annulus situated after the first eleven rows of blading. By this means the turbine can produce a greater power up to 6,250 K.W. with a very slight sacrifice of efficiency.

There are 38 pairs of rows of blading in the turbine, the first 31 of which are of the "end tightened" type, the rest being "radial clearance" blading.

The growth in turbine manufacture and design was well exemplified in the exhibit by placing alongside for comparison a small set, built 44 years ago. The speed of this little machine is 18,000 r.p.m. and it develops 4 K.W. It is similar in type to those which supplied the current for lighting the Newcastle Exhibition in 1887. Turbo alternators have been built by Messrs. Parsons up up to 50,000 K.W. each, and even larger are now proposed.

The alternator end of the turbo-generator shown was of the totally enclosed high speed type, designed for 6250 K.W. three-phase at 11,000 volts, 50 periods, 0.8 power factor. The machine is of the most modern design and incorporates the latest improvements in turbo alternators. The stator, or stationary field casing, is of cast iron into which are built the insulated laminated iron plates forming the core. These plates are assembled under heavy pressure and are securely held by massive circular end plates, which carry strong inwardly projecting steel fingers to support the core between the conductor slots. The core conductors are of the Parsons patented helically stranded coreless cable, the individual wires being insulated and spiralled in a definite lay to eliminate eddy currents. The strip end connections are well spaced permitting good ventilation and are securely braced and clamped.

The rotor, or revolving field magnet, was of the barrel type, the excitation winding being accommodated in radial slots milled out of a solid steel forging. An axial hole was trepanned through the centre of the shaft to enable the forging to be examined for soundness before completing the manufacture. The windings are of copper strip and the insulation is mica. The rotor end windings are efficiently packed with moulded heat-resisting packings and are held securely in position by mas-

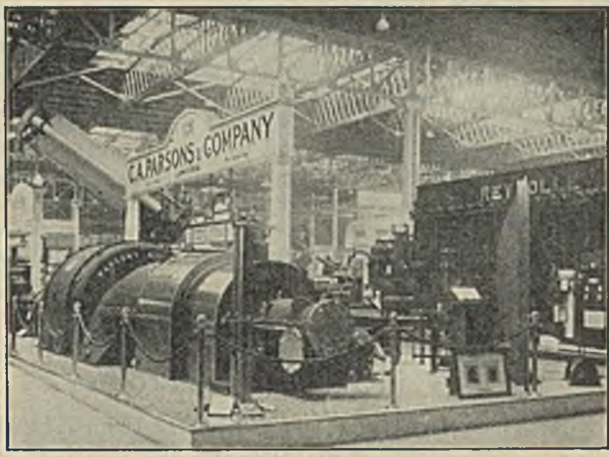


Fig. 1.—Exhibit of C. A. Parsons & Co., Ltd.

sive high-tensile weldless nickel chrome steel end caps which in turn are supported by the rotor body and strong steel end rings.

The excitation is provided by an "overhung" exciter, the armature being mounted on an extension of the rotor shaft.

The alternator is ventilated by the Parsons system which admits cool air along the whole length and circumference of the stator ensuring uniform ventilation and effective cooling of the stator core, the stator end windings, and the rotor. To maintain a continuous supply of clean cool air to the alternator, the closed system of forced ventilation, using a surface air cooler, is employed; the same air is continually re-circulated by integral fans mounted at the ends of the rotor. The heat imparted to the air when passing through the alternator is dissipated as it passes through a surface air cooler, which is incorporated in the alternator foundation block. An air alarm device for indicating the air outlet temperature was fitted: this comprised an index thermometer mounted on the side of the stator casing, which is electrically connected to a device for operating a Klaxon horn and lighting a lamp. The device

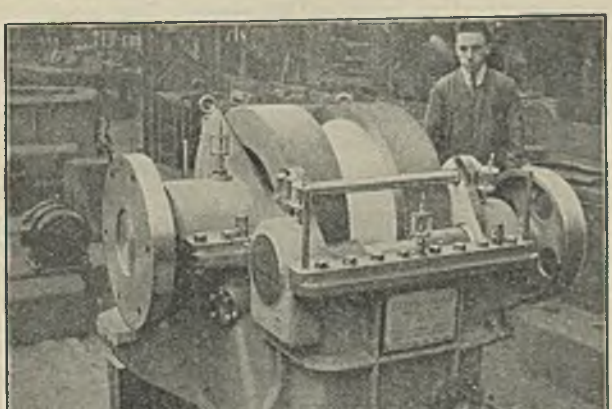


Fig. 2.—A Parsons "Creep-cut" Gearing.

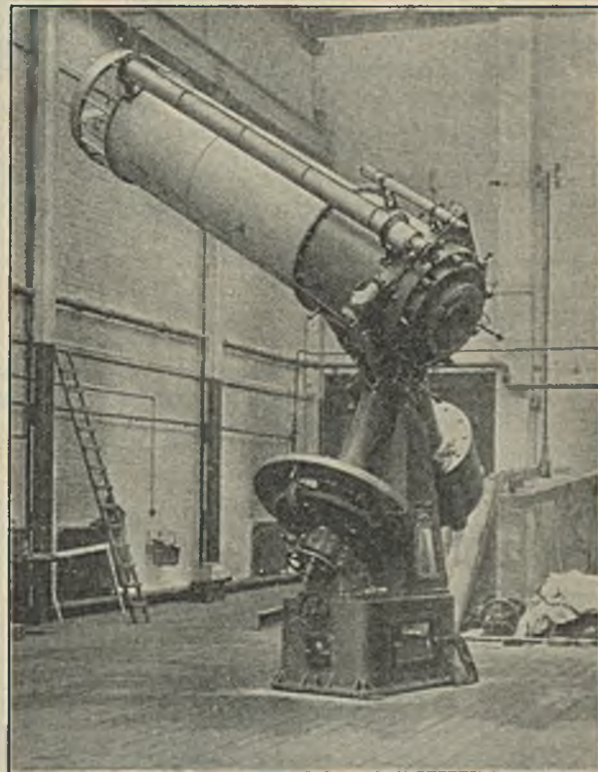


Fig. 3.—The Parsons' Telescope.

operates when the temperature of the outlet air from the alternator reaches a pre-determined figure.

Another exhibit consisted of a gear-case with wheel and pinion of the Parsons "Creep-cut" pattern designed to transmit 670 B.H.P. at 5000/600 r.p.m.

Telescope.

A prominent and popular exhibit was the huge astronomical reflecting telescope of 3 ft. aperture constructed by Sir Howard Grubb Parsons & Co., a subsidiary of Messrs. C. A. Parsons & Co., Ltd. This telescope had been built for the Royal Observatory of Edinburgh, and is the largest reflecting telescope in Great Britain.

Searchlight Reflectors.

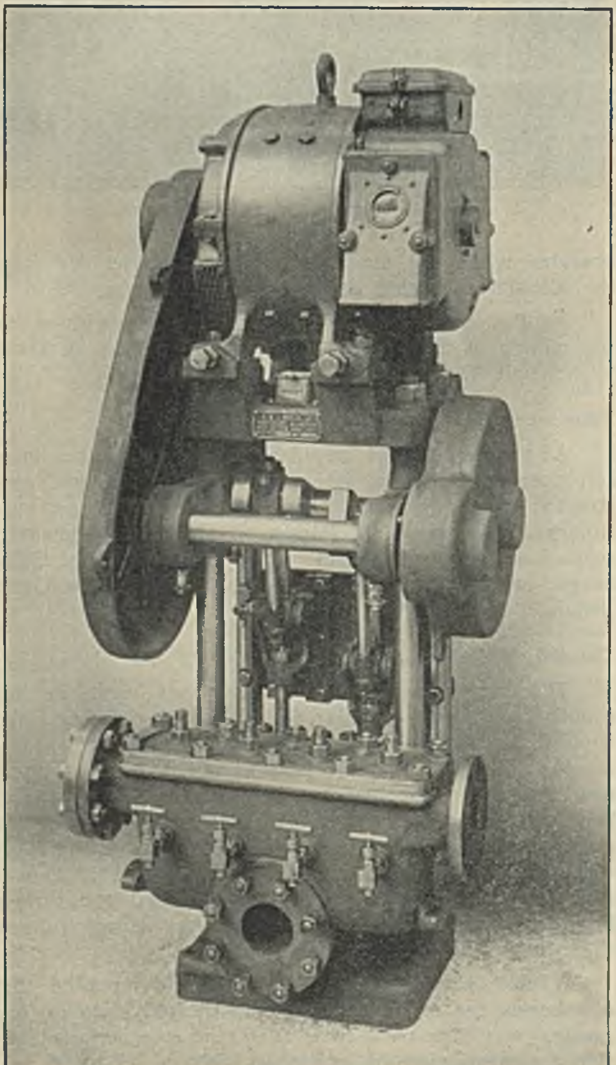
The largest searchlight reflector yet made in this country was also a popular feature. It is 220 cms. diameter (7ft. 2½ins.) and of 100 cms. (3ft. 3⅜ins.) focal length. The reflector was shown mounted in an angle ring ready for attachment to the back of a projector, and weighs independent of the mounting 420lbs. It is made of glass about 9/16in. thick and accurately figures to a paraboloid surface inside and out. This glass was then coated with silver chemically deposited and further by a coat of copper, the whole being protected by a sheet lead and wire netting backing.

A split parabola ellipse reflector, so mounted that two beams can be obtained at any desired angle to one another was also on view. This type is especially suitable for navigation of canals and rivers by night. In such work it is necessary to have a beam which will light up the buoys at the sides of the canal and at the same time leave a dark centre, so as to prevent the pilot of an approaching vessel being dazzled by the light from the projector.

A searchlight was installed in each of the two towers at the Exhibition, and the reflectors for these were manufactured by C. A. Parsons & Co., Ltd. They were 90 cms. in diameter and of 42 cms. focal length. Another 90 cm. diameter reflector was exhibited on the stand.

G. & J. WEIR, Ltd.

In conjunction with their associated Company, Drysdale & Co., Ltd., this firm exhibited a notable series of their well-known pumping and power station equipments. The examples included a multiflow feed water heater; a monotype air pump; a two-throw pump, 7in. by 7½in., electrically driven and of the capacity of 16,300 gallons of water per hour at 75 r.p.m. against 80lbs. per sq. inch pressure; a two-throw pump, 4in. by 4½in., electrically driven for a duty of 4,250 gallons of water per hour at 100 r.p.m. against 80lbs. pressure; a 10-ton evaporator with feed regulator and brine ejector, producing 10 tons per day of 24 hours; a contraflo boiler feed regulator; a horizontal oil fuel pressure pump; a pair of boiler feed pumps, 7in. by 9½in. by 21in., with float tank. Other interesting items included a three-stage air compressor coupled to a 60 b.h.p. electric motor. The several Drysdale exhibits included a patent "Pervac" condensate extraction pump for a duty of 180,000lbs. per hour.



Weir Electrically Driven Pump

A New Metal-Coating Process.

A notable improvement in methods of coating metallic and other bodies with protective film coverings of other resistent metals has been introduced by Metals Coating Co., Ltd. It takes the form of a hand-wielded pistol in which any metal that can be drawn into wire may be used for the coating material. The zinc, aluminium or other wire is fed through the pistol from the back and drawn automatically from a reel through the nozzle into contact with an oxy-acetylene flame which melts the wire; compressed air then blows the atomised metal against the surface to be coated at a velocity of about 3000ft. per second. The metal, as it impinges against the surface at this high velocity, solidifies and practically becomes an integral part of the surface. This metal-spraying pistol weighs only 3½lbs., and is manipulated by hand for most work. In many cases, particularly in coating large structural members, etc., the tool must be taken to the work, and this may readily be done, whether in the shop or out in the open.

By this means "Aluminising" as a patented process for the protection of iron and steel from scale, etc., due to exposure to high temperatures, is being commercially used for such parts as engine manifolds and exhaust pipes; super-heater tubes; case hardening, annealing and cyanide pots; parts of electric furnaces, fires and cookers. The aluminium coating process is applicable to many other parts that must repeatedly withstand high temperatures, and their durability has in some instances been increased as much as 100 times. The coating of iron and steel with zinc by this metal-spraying process is cheap and efficient. A sprayed zinc coating of 0.0004in. thickness gives a protection equivalent to the best hot dip galvanising, and, of course, has the great advantage that work of any size can be treated *in situ*, if necessary, while there is no possibility of distortion of intricate articles. The interior surfaces of tubes, even though small and of considerable length, may be coated readily by using a special internal attachment in conjunction with the tool. When comparatively small pieces are to be coated in bulk, a mass coating machine is used in conjunction with the hand pistol. This mass coating machine resembles a tumbling barrel which turns the mass of parts over and over continually, presenting new surfaces to the jet of atomised metal.

Metallic coatings can also be applied by this method to non-metallic surfaces such as wood, stone, brick, glass, porcelain, concrete, leather and fabrics. The thickness of the coating may be varied, according to requirements, from 0.001in. up.