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Revelations of Folly.

The Annual Report of H.M. Electrical Inspector of Mines always contains a large assortment of facts and statistics concerning the development of electrical services in and about mines. Useful as those records undoubtedly are, the greater common interest in the book centres round its unique aggregation of facts and opinion concerning accident and tragedy. Mining electrical accidents are, happily, few and far between: as far as mining accidents from all causes go, the electrical kind are comparatively rare: so it is only by bringing accounts of all the electrical accidents of a whole year together for critical comparison and survey that their importance is shewn.

From one point of view—that of the critic disgruntled with the world in general—it is more than disconcerting to know that there are still some men who can be so utterly foolish as to play about with live terminals, to put current into partially assembled machines, to ignore deliberately the simplest obvious measures and rules devised for their particular benefit by plant makers and by experienced engineers and miners.

Another kind of critic, less intolerant of human frailties, will find much compensatory satisfaction in the knowledge that the use of electricity in mines now involves no special risk and is indeed remarkably safe: his devout wish is "Oh that men could mend their ways": but it is so easy to perfect the machine and it is so hard to improve the man. The greatest need is always for the difficult task. To make better men is still the most pressing call. We do not, however, propose on this occasion to dwell upon education—the inference is clear.

Mr. J. A. B. Horsley (H.M. Electrical Inspector of Mines) in the course of his general comment on the fatal accidents finds it necessary to emphasise the gross inattention of engineers to the requirements of General Regulation 131(g) which demands adequate facilities for the positive earthing of terminal switchgear and similar apparatus. He mentions that he has again approached the manufacturers with a view to having them incorporate such modifications or additions to their gear as will make the earthing connection a certain and integral part of normal operations. Furthermore, Mr. Horsley has included as an Appendix to this Report a more detailed enunciation of the principles and methods of earthing described in the Mines Department Circular No. 23 of January, 1927. This Appendix C. with its diagrams, is reprinted in this issue (see page 240).

Another useful chapter concerns the method of linking-in lengths of pliable armoured cables and trailing cables for the safe and convenient advance of gate-end connections. This also is reprinted herein as a ready and permanent reference for readers engaged in mining practice. It is important to make quite clear that the methods advocated by Mr. Horsley can be applied by means of standard appliances already available and, consequently, there is no excuse for ignoring the recommendations, nor for indulging in the much too common condemnatory practice of hitching together a home-made contraption "just as good".

Those who read carefully through these reports of accidents will see how often tragedy has followed in the wake of the hurried and thoughtless use of near-at-hand make-shift expedients. Is there any excuse for patching up trailing cable plugs with odd strands of copper wire twisted round them? Or for having more than four hundred yards of trailing cable with its half-dozen plug and socket connectors worming the wet and tortuous track from gate-road switch to face? Or for using a coalcutter with a flame-proof cover of which three of its four fixing set screws were missing and the fourth lying in its hole with a stripped thread? All these short-sighted practices resulted directly in tragedy, in the last case nine lives paid the penalty.

There is no necessity to quote chapter and verse, they are all set out in this Report and every conscientious mining electrical man will not let the price of ninepence stand between him and the knowledge to be gained by reading it for himself.

Lest some may shrink from the perusal of a distressful account of accidents which they know already only too well do take place now and then, it is of the greater importance to mention that in every case Mr. Horsley closely analyses cause and effect, and recommends sure and practical remedies for defects and means for prevention. For example, he tells what cables are safest and what switchgear is best, he advocates contactor relay control for coalcutters, and so on. For obvious reasons he does not specify this or that or any particular maker's goods or equipment: but he instructs the reader so very clearly that any practical mining electrical man worthy of the name will without difficulty be able to select the right stuff.

There is no other book in existence which can in a nutshell give the mining electrical engineer anything like so much information that is invaluable to him in his vocational pursuance of safety-cum-maintenance.

Oil from Coal.

A special contributor of *The Mining and Industrial Magazine of Southern Africa*, writing with particular reference to the duties and functions of the national Fuel Research Institute (S.A.), speaks very confidently of the early development to the commercial and industrial stage of power-oil and spirit derivation from coal. He states that the practicability of liquifying the bituminous coals of the Union into high grade petrol by hydrogenation is no longer an academic question, as is patent to anyone who has followed oil-from-coal developments overseas. German experts connected with the I.G. Farbenindustrie have definitely stated that bituminous coals yield an even better petrol than is obtained from brown, or lignite coals for the reason that the former class of coal contains a higher percentage of aromatic compounds. In other words petrol obtained from brown coal is paraffinoid in nature, whereas that from bituminous coal is aromatic in nature, and possesses higher anti-knock qualities which of course makes for higher compression in internal combustion engines.

It can thus be taken for granted that the crude oils obtained from our (S.A.) coals can by hydrogenation be converted into high grade petrol and other high quality oils. It is further claimed by oil experts that low temperature tar from coals which contain a high percentage of phenolic compounds is more difficult to refine than the crude oil obtained by the hydrogenic process. The addition of tar oil is essential in large scale production in order to facilitate the pumping of the raw material into reaction retorts. It may also be pointed out that 41 to 53 per cent. of Witbank coal can be converted into crude oil, as shewn by local experiment, even without the use of catalysts. There is thus no warrant for the contention that bituminous, or hard coals, are not amenable to hydrogenation.

Some doubts have been expressed concerning the economic aspect of petrol from coal production in Germany. Last year the I.G. Farbenindustrie produced 138,000 tons (43,000,000 gallons) of petrol at their great refining plant at Leuna, from local brown coal deposits, mixed with low temperature tar. The reason brown coal is used is that Leuna is the centre of the brown coal fields of Central Germany. As a result the Standard Oil Co., of New Jersey, and the Dutch Shell Co., have sunk a lot of capital in a three-cornered combine, including the I.G. Farbenindustrie, in order to undertake the distribution of synthetic petrol in Germany itself, and to handle all petrol-hydrogenic patents throughout the rest of the world.

In the last annual report of the Standard Oil Co., it is stated that, through hydrogenation it is now shewn to be practicable to convert coal into liquid hydrocarbons at a cost which although above prevailing oil prices (American prices presumably) is not prohibitive. Thus the coal reserves of the world become supplemental to the crude oil (oil-wells) reserves. By the hydrogenation method liquified coal, shale oil, coal tars, crude petroleum and its residues of all descriptions may be converted into substantially 100 per cent. high grade finished products.

Whether petrol or crude oil is going to be the motive force of transport in the future hardly affects the question at issue. Either, or both classes of oil would have to be imported under existing conditions, so that whether the proposed new oil industry simply produces the crude oil or converts it into petrol by hydrogenation, is a matter that can safely be left to the technical advisers of the Institute. The only point that admits debate is the capacity of the local demand in the interior to warrant production of our own fuel oils. There is a notable increase in motor lorries already being driven on crude oil.

Crude oil engines for the production of power on the outside mines, and for pumping plants and farming machinery generally, are being installed on all sides. All the signs go to shew that small communities of people will adopt crude oil power for manufacturing concerns, for the generation of electricity, as well as for road mechanical transport. Thus the production of crude oil on an economic basis seems more assured than was the case with many other secondary industries that have been built up.

It may be pointed out that the consumption of petrol in the Union of South Africa has trebled during the past four years. The Union at present imports more than 100 million gallons per annum of petrol, paraffin, lubricating and fuel oils. There thus appears to be every justification for the claim made that there is a big enough internal local market for either petrol or crude oil to warrant the development of the proposed oil-from-coal industry.

* *

Mr. C. J. Hyde Trutch, of the Diesel-electrical Traction Department of Sir W. G. Armstrong Whitworth & Co., Ltd., speaking at a meeting of the Institute of Transport in London, contended that many advantages would be obtained if British railways adopted the oil-electric engine in place of the steam locomotive. He estimitated that the annual savings would be: Maintenance, £6,000,000; Fuel, £8,400,000; Engine staff wages, £4,000,000; Water, £850,000; Total, £19,250,000.

It might be argued that the colliery companies would raise some outcry against the importation of oils to take the place of home-produced coal, but the 13,400,000 tons of coal consumed by the railways represented only 5.2 per cent. of the tonnage raised in 1929, and a small reduction of freight rates made possible by reduced operating expenses would, by increasing the competing power, be of far greater value to the collieries than the lost railway purchases. The time was not far distant, however, when sufficient oil would be produced from home-mined coal.

British Industries Fair : Birmingham.

Greater and more representative than ever will be the magnificent display of heavy goods at the Birmingham Section of the British Industries Fair next month. Every inch of the space available has been taken up, many firms have been unable to obtain the full areas they would have desired, while numbers of later applicants failed to receive any allocation at all.

While extensions were continually being made to the series of buildings now thrown into a single hall, one-third of a mile long, there were practical difficulties in bringing the various industries and allied trades together; the task, arduous as it has been, is justified by the success attending its accomplishment. Buyers will for the first time have grouped and arrayed before them, in effective and composite manner, the respective classifications of goods which are of primary interest to them.

Preliminary advices received from sixty per cent. of exhibiting firms shew an unusual increase in the number of new goods and processes to be displayed. Based on these returns, it is estimated that at least two thousand entirely new products in the engineering and kindred trades will be open to inspection.

A particularly welcome improvement is the assurance that trade visitors, who in past years had great difficulty in securing hotel reservation, will be helped in this connection by the arrangements devised by the organisers.

Proceedings of the Association of Mining Electrical Engineers.

NORTH OF ENGLAND BRANCH.

A Modern Coke Works.

SIDNEY A. SIMON, M.A.

(*Paper read 15th November, 1930*).

During the Annual Convention of the Association held in July, 1929, in Newcastle, a visit was paid to the Derwenthaugh Coke Works of the Consett Iron Company, Limited, which is one of the finest examples of a modern coke oven and by-product recovery plant in the country. An article briefly discribing the process with a progress diagram and illustrations of general views of the plant appeared in the July, 1929, number of *The Mining Electrical Engineer* (Vol. x., No. 106, pp. 31-35).

For the benefit of those who could not take part in the visit and also as a reminder to those who were able to be there, this paper has been prepared to supplement that article with a more detailed survey of the electrical engineering and some other cognate features of the plant.

HISTORICAL INTRODUCTION.

As an introduction to the subject matter of an ultra-modern coking plant, a few brief historical notes on the making of coke and its by-products in this country may be of interest.

Coke.

The process of coking, or cooking, coal appears to have been introduced towards the end of the 16th century in connection with efforts then being made in various directions to substitute coal for wood and charcoal. In the year 1590, a patent was granted to John Thornborough, Dean of York, "to purify pit coal and free it from its offensive smell".

In 1620 a grant was made to a company "for charking sea coal, pit coal, stone coal, turf, peat, etc., and employing the same for smelting ores, and manufacturing metals, and other purposes". In 1627 a patent was granted "for a method of rendering sea coal and pit coal as useful as charcoal for burning in houses without offence by the smell or smoke".

Again, in 1633, a patent was granted "for a new way of charking sea coal and other earth coal and for preparing, dressing, and qualifying them for the melting and making of iron and other metals and many other good uses" (probably introducing some continental system of coking, judging by the foreign names of some of the patentees).

Fuller, writing about that time on Shropshire coal, exclaims "Oh ! if this coale could be so charked as to "make iron melt out of the stone as it maketh it in "smith's forges to be wrought in the bars—but 'Rome "was not built all in one day' and a new world of "experiments is left to the discovery of posterity."

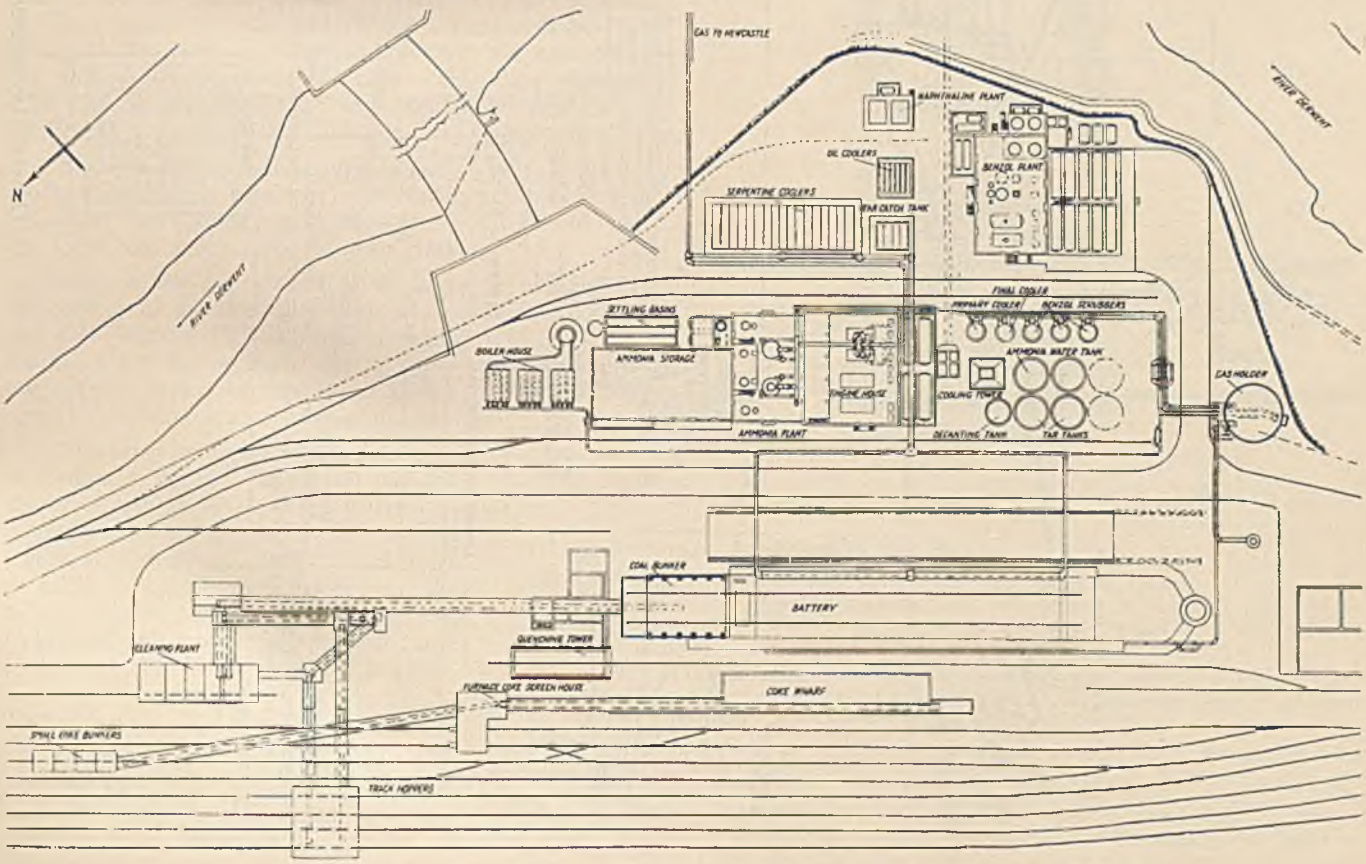


Fig. 1.—General Layout of a Modern Coke Oven Plant—Derwenthaugh.

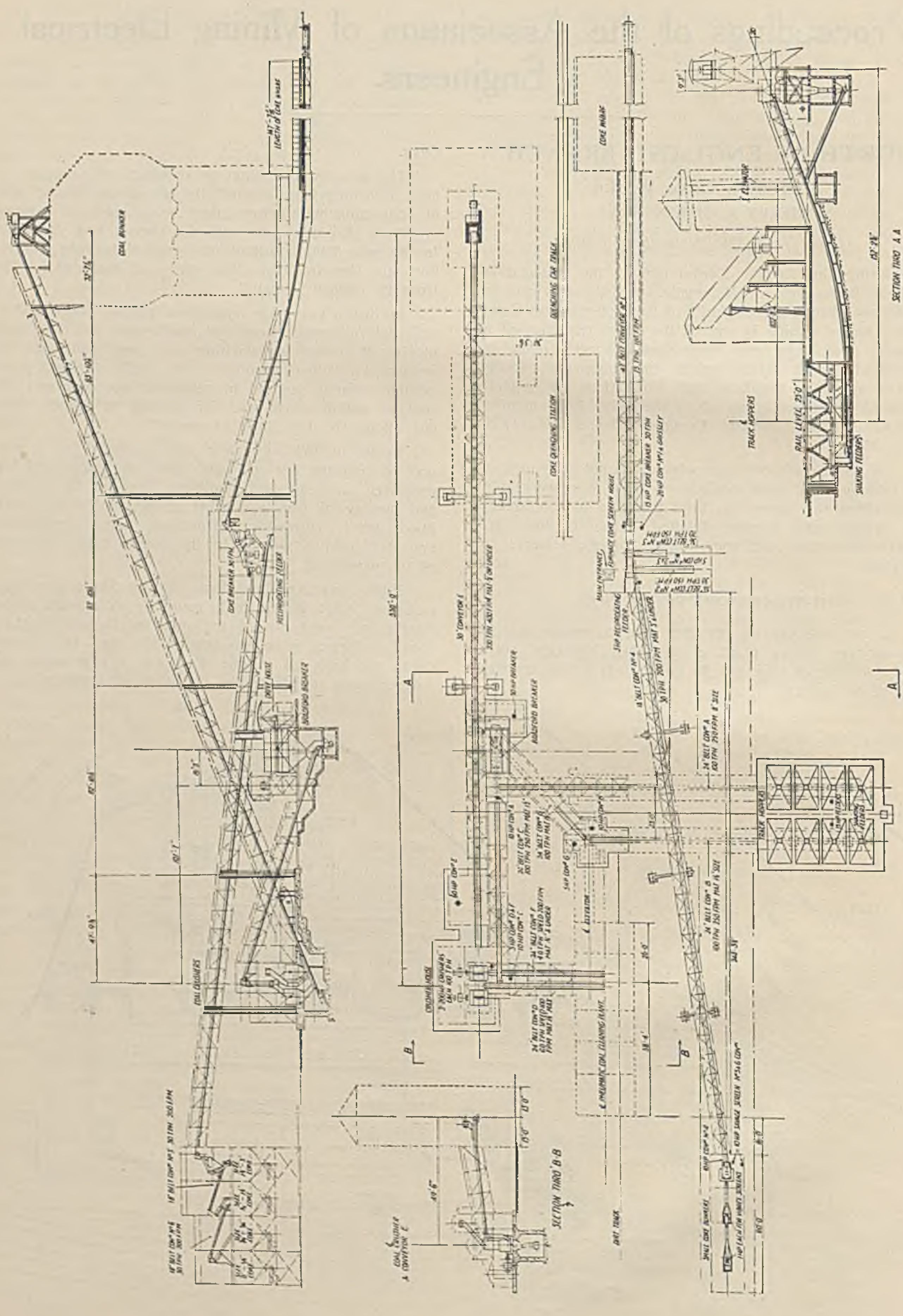


Fig. 2.—General Arrangement of the Coal and Coke Handling Plant.

Whatever amount of success may have attended the attempts which continued to be made, a considerable time elapsed before the manufacture of iron with coke began to assume any degree of practical importance.

Among other coke-making projects was one utilised by Sir John Winter for a superior household fuel. His method is thus described by Evelyn in his diary under date 11th July, 1656 :—

"Came home by Greenwich Ferry, where I saw "Sir John Winter's new project of charring sea coales "to burne out the sulphure and render it sweet. He "did *it* by burning the coales in such earthen pots as "the glassemen mealt their mettal, so firing them without "consuming them, using a barr of yron in each crucible "or pot, which barr has a hook at one end, and so the "coales being melted in a furnace with other crude "sea coales under them, may be drawn out of the "potts sticking to the yron, whence they are beaten "off in greate halfe exhausted cinders, which being "rekindled make a cleare pleasant chamber fire, deprived "of their sulphur and arsenic malignity. What success "it may have time will discover."

From the middle of the 17th century the employment of coke in drying malt was practised in Derbyshire and the change to this mineral fuel from straw was considered to have effected a decided improvement in the quality of the brewings. "The reason of Derby "malt being so fine and sweet," says Houghton (collection of letters, 1727), "my friend thinks is the drying "of it with cowks which is a sort of coal (so called "there)"; and he proceeds to describe how "the colliers "cowkified the coal in large round heaps of 6 or 8 "wagon loads built in as pyramidal form as they would "stand."

Coke ovens are stated to be first mentioned in 1763 (Trans. N.E.Inst. xv. 208) though reference to coke making in the North occurs at least 10 years earlier. M. Jars speaks of the existence of 9 furnaces on the banks of the river at Newcastle in 1765 for destroying the sulphur contained in the coal. This date coincides with the commencement of the regular importation of cinders into London—393 chaldrons (501 tons) in 1766.

In 1800 some manufacture of coke or, as it was more commonly termed in the North at this period, "cinders" was going on in the Northern coalfield both for local consumption and for exportation.

Coke ovens are spoken of as being in existence at the outcrop of the Brockwell seam at Cockfield, Woodlane and Old Woodifield Collieries in South Durham; but the ordinary way of burning coke is stated to have been in the open air in what are called cinder rows.

The process of manufacturing coke in ordinary beehive ovens as pursued at the Duke of Norfolk's Collieries is minutely described by Parks in his Chemical Catechism, 1822. There were a great many of these ovens in the neighbourhood of Sheffield in 1835. Coke was also produced by piling large coals in long rows without ovens.

By-Products.

In the later part of the 17th century the manufacture of pitch, tar, and oil from minerals began to attract attention: a patent was granted to Becker and Searle in 1681, and in 1694 another patent was obtained by one Ele. The earliest reference to this subject in the North of England occurs in a notice of the death of one Baron von Haeeke of Gateshead in 1780, described as a native of Silesia, who had come to this country for the purpose of extracting tar from coal.

Lord Dundonald took out a patent for extracting coal tar and other products from coal in 1871. His contemporary Williams, writing in 1879, deprecates it as a pernicious manufacture save when carried on in connection with iron works where the coke produced could be utilised for smelting purposes.

Coal Gas.

The early years of the 19th century witnessed the advent of an altogether new branch of the coal trade in the distillation of the mineral for the manufacture of gas. Coal then, for the first time, became a source of light.

To William Murdock, a native of old Cumnock in Ayrshire, Scotland, belongs the credit of first applying gas distilled from coal to purposes of practical utility. From his paper communicated by Sir Jos. Banks to the Royal Society, 25th February, 1808, it appears that Murdock lighted up his house at Rednith in 1792.

It is only, however, in quite recent years that the manufacture of gas has been combined with the production of metallurgical coke and other by-products—the period which coincides with the evolution of the modern coke works.

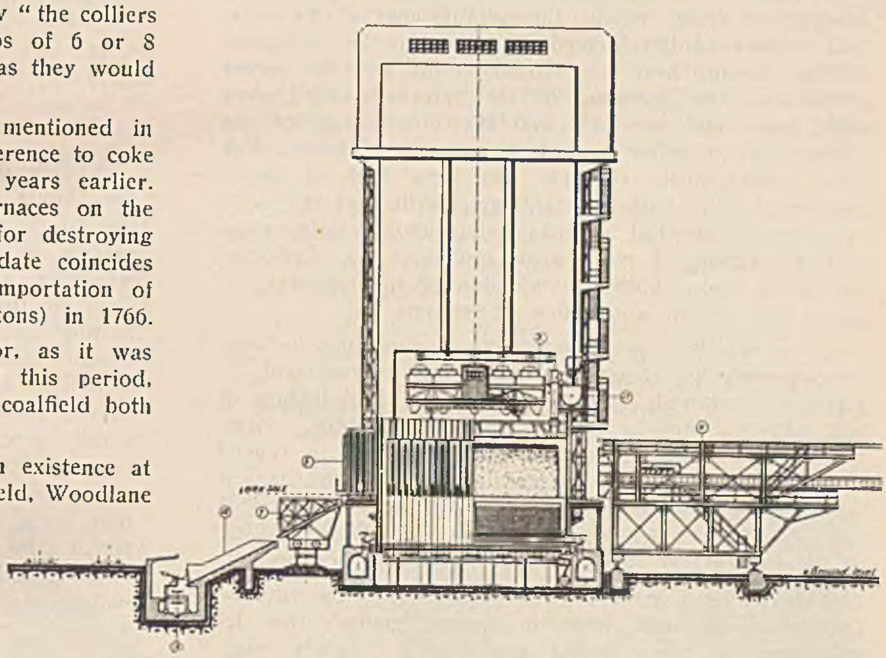


Fig. 3.—Elevation and Part Section of typical Modern Coke Oven.

(a) *Coal Storage Bunker with Elevator.*

(3) *Coal Larry which runs along the top of the Ovens, receives coal from under the storage bunker, and discharges it through five chutes into the oven. (The oven is shewn in half section and the hairpin flues in oven wall in the other half section.)*

(4) *Pusher Machine with Leveller to distribute the charge evenly in the oven. Ram to push the burnt-off coke out of the oven; it also carries machinery for lifting, removing and replacing the oven door.*

(5) *Coke Guide through which the coke is pushed into the Quenching Car (7): this also carries machinery for lifting, removing, and replacing the oven door.*
An electric locomotive pushes the car with the red hot coke into the quenching tower and after quenching and draining the coke is discharged thro' pneumatically operated doors on to the sloping coke wharf (12) from which it is eventually transported by the main coke conveyor (13) to the coke screening plant.

TABLE I.

Plant Date	*No. of Ovens.*	*Type*	*Length*	*Height*	*Mean Width*	*Cu. Capacity Coal*
1.—1906	55	Waste Heat	32 ft. 7 ins.	6 ft. 10⅜ ins.	1 ft. 8¾ ins.	316 c. ft.
2.—1908	50	Waste Heat	32 ft. 7 ins.	7 ft. 2⅝ ins.	1 ft. 8¾ ins.	350 c. ft.
3.—1914	75	Waste Heat	32 ft. 7 ins.	7 ft. 6½ ins.	1 ft. 8¾ ins.	350 c. ft.
4.—1923	60	Regenerator	37 ft. 3 ins.	10 ft. 6 ins.	1 ft. 5¾ ins	500 c. ft.
5.—1929	56	Regenerator	41 ft. 6 ins.	13 10⅜ ins.	1 ft. 5¾ ins.	770 c. ft.

TABLE II.

Plant Date	*No. of Ovens.*	*Type*	*Length*	*Height*	*Mean Width*
S.—1926	70	Regenerator	40 ft. 0 ins.	11 ft. 6 ins.	1 ft. 5¾ ins.
B.S.-1927	72	Regenerator	45 ft. 0 ins.	14 ft. 10 ins.	1 ft. 5¾ ins.
P.—1928	180	Regenerator	42 ft. 0 ins.	13 ft. 3 ins.	1 ft. 5¾ ins.

MODERN COKE WORKS.

A modern coke works is the outcome of steady development in the elimination of waste by more thorough recovery of the valuable constituents of the raw coal, as well as by more economical production of the various products, and in the improvement in quality of those products to meet the demands of an increasingly discriminating market.

From the old-fashioned beehive oven with its hand labour and waste of all the volatile matter, the principal stages of development have been: the utilisation of the surplus heat for raising steam and for power production, the invention of the externally fired oven with by-product recovery, and the introduction of the regenerative principle and conservation of rich gas. For these achievements recourse has been had in ample measure to the highest engineering skill and the wide resources of chemical and physical technology. Invention and adaptation of mechanical appliances have effected saving of labour both by reduction of the numbers engaged and by the elimination of irksome toil.

One of the most important factors in post-war development has been the enormous improvement in refractory materials and particularly the introduction of Silica Bricks into the construction of the ovens. Much research of highly specialised character, both in regard to the admissible temperatures and to the mechanical strength, were necessary for this achievement. The result has been the enlargement of the ovens, the curtailing of the coking time, and marked economy in heating.

The Table I. gives particulars of some representative Durham plants and shews in marked manner this development in size: whilst the Table II. gives comparative figures for some recent German batteries.

As illustrating the improved economy the following is extracted from a recent discussion on "Heating Economies in Large Coke Ovens" by the Northern Section of the Coke Oven Managers' Association, on 26th September, 1929—

"Now that the sale or use of Coke Oven Gas "has become so important, it is necessary to consider "the production of the maximum quantity for disposal. "In ovens heated with their own gas it is only after "their heating requirements have been met that there "is any surplus, and this can only be increased by "effecting economics in the heating of the oven. The "following are comparative figures from old and new "Ovens." (Shewn here as Table III.):—

TABLE III.

COMPARATIVE FIGURES FROM NEW AND OLD OVENS.

Average width of oven in inches	*Capacity in tons*	*Coking time in hours*	*B.T.U. required per lb. of coal carbonised.*
19½	16	18	1000 *
13¾	11.7	11	1095 *
—	15	15	1300 to 1400 *
18	11.25	15	1120
18	17	15.5	890

* From "Coal Carbonisation" by Porter.

"These figures shew that the largest ovens require "the lowest B.T.U. per lb. of coal carbonised. It is "due to the following reasons. 1. The smaller exposed "outside area of the battery per ton of coal carbonised, "which has a lower radiation loss, sometimes amounting "to 7 to 10 per cent.; 2. the increased height of the "heating flues in large ovens; 3. the improvements in "design, such as thin walls, hair pin flues, large re-"generators with special fillings, gas feeds beneath ovens "having cast-iron gas nozzles instead of clay nozzles, "which give better regulation and prevent uneven "heating. An important point is quick scavenging during "change-over period. 4. Improved methods of opera-"tion, such as regular pushing and charging of ovens "which give a uniform heating gas, automatic regulation "of draft, gas pressure, and pressure in collecting mains; "with a recording calorimeter not only is the surplus "gas kept constant but also the heating gas.

Continental Progress.

Most significant is the extent to which the modern large high speed coke ovens have been adopted abroad. The following information is from a German source regarding modernisation in the Ruhr industrial district (Stahl und Eisen (1929) p. 130) and also from the "Gas Journal" dated 19th June, 1929:—

In 1926 there were 140 coke works with 16,200 ovens producing 28,000,000 tons (metric) coke per annum. By the end of 1927, 2770 new ovens had been built on 32 plants, of which 1060 were to extend and complete 14 existing works, while 1710 were built on 18 new plants.

Since then 36 large plants (i.e., the 32 mentioned above and 4 older ones) with under 7000 ovens can produce 24.9 million tons of coke per annum, of which 15.3 million are produced in the 2770 new ovens.

Similar developments have proceeded in other Continental industrial districts and the growth is astounding in comparison with the reconstruction of ovens in this country.

Along with the reconstruction on most economical lines of coke oven plants abroad, elaborate schemes have been worked out and put in hand for the wholesale long distance transmission of gas for supplying large towns far beyond the boundaries of the industrial districts.

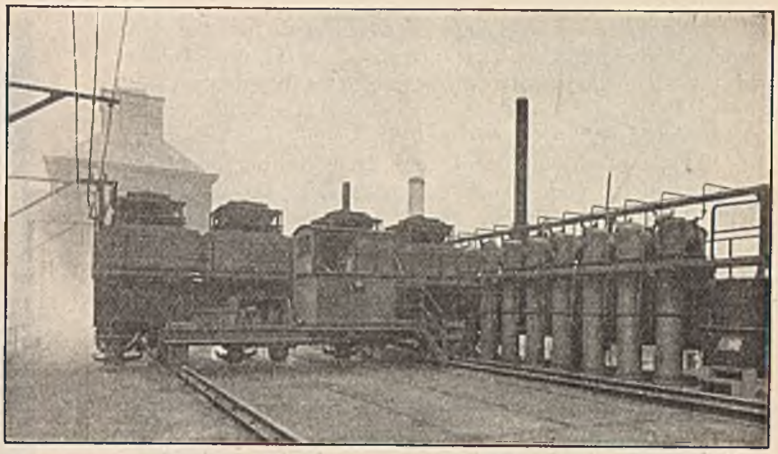


Fig. 5.—Modern Coal Lorry.

Electricity in Connection with Coke Works.

It is of particular interest to this Association to consider the contribution of electrical science and engineering to modern coke works practice. As in so many other industries, electricity plays an important, if not a primary part.

From the figures already quoted in the article previously referred to, regarding the number and power of the motors, as well as from what is stated below, electricity may almost be considered the maid-of-all-work.

THE DERWENTHAUGH COKE WORKS.

Reverting to the Derwenthaugh Coke Works, owing to the importance of the electrical installation in relation to the efficient working of the whole plant, consideration was given to the electrical equipment in regard to its general layout and the major items of plant and process, almost immediately after the main contract for the coke works plant had been let, and even before many of the mechanical details had been definitely settled. This was somewhat of an innovation in coke works practice, in which so often the electrical installation has been left over until almost the last and then put in hurriedly, resulting in an appearance of the electrical services having been an afterthought and obviously not so good as they might have been.

One advantage of this early electrical planning was that suitable places could be allocated from the start for housing electrical apparatus, etc., and rooms of ample size with plenty of natural light were set apart, instead of having to use dark and dusty basements as was so frequent in the past.

As work proceeded, alterations were necessary to meet evolutionary technological improvements but, with few exceptions, these could be worked in without difficulty, owing to the elasticity of the original scheme.

Arrangements had been made (as incidentally mentioned in the previous article *vide The Mining Electrical Engineer,* p. 34, No. 106, to supply gas to the Newcastle and Gateshead Gas Company. Fig. 12 is a map of the district shewing the gas and electric mains. It was anticipated that initially and seasonally there would still be a surplus of gas; it was therefore decided to put down a power station with larger units than the coke works alone would require. There were to be two such units, each to supply the full requirements of the coke works with a very large margin, and it was further prescribed that the boiler plant should be sufficient to provide steam for all the coke and by-product plant requirements together, with both generating sets working at full load.

The works' demand was estimated at 500 k.w. to 600 k.w. maximum (when crushing in 10 hours per day) and generating sets of 1000 k.w. maximum continuous rating were decided upon.

The surplus power was to be transformed up to from 5500 volts to 6000 volts and transmitted by overhead lines to the Company's colliery electrical system, a distance of six miles to their Chopwell Power Station. The existing frequency of 50 periods was therefore chosen.

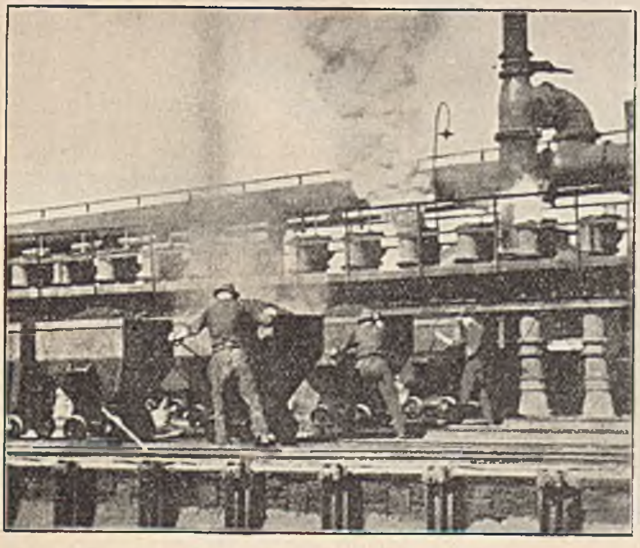


Fig. 4.—Old Method—pushing Loading Car.

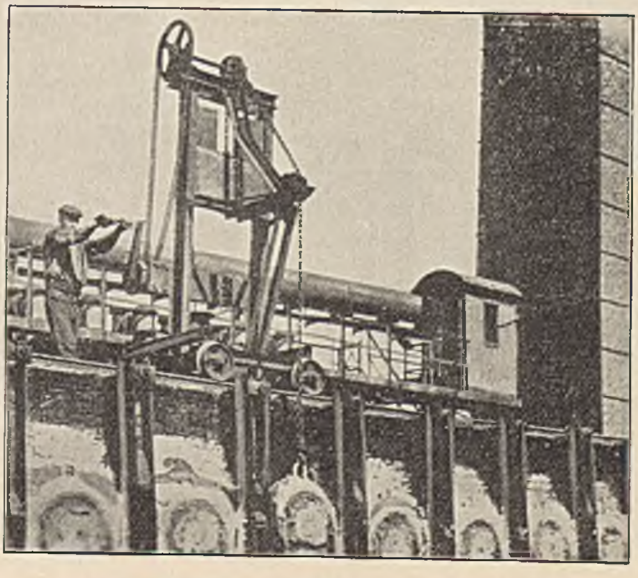


Fig. 6.—Old Method—Hand Winch for Oven Doors.

A voltage of 525 volts was selected for the coke works distribution, as that pressure was in use at other of the Company's coke works and establishments.

Electrical Generation and Transmission.

The power equipment and transforming plant are situated in the main machine room sharing the floor space with two turbine-driven gas exhauster booster sets.

Figs. 13 and 14 shew a diagram and photograph respectively, of the main generator. The two turbo generator sets of 1250 k.v.a., m.c.r., comprise Rateua impulse turbines at 5000 r.p.m. geared to 1000 r.p.m., three-phase, 50 period, 500/550 volt alternators. They were the first of their size in a new self-contained type which the makers had developed specially for marine and industrial purposes. The design represents a radical departure from previous standard practice; the condenser body forms the bottom of the turbine casing, and the auxiliaries are mechanically driven from the main shaft; the whole forms an exceptionally simple and compact arrangement which, apart from the high efficiency obtained, has the obvious advantage of being an ideal "one-man" set, capable of being put on the bars with the minimum of trouble and time, and obviating the disadvantages of independent auxiliaries.

As will be seen from the illustration, Fig. 14, the turbines are at the switchboard ends of the sets, almost immediately opposite and close to their respective generator panels.

The positive drive of the auxiliaries ensures that the maintenance of vacuum is not affected by electrical interruptions or faulty switching, while the whole output of the generators is available for external load.

Under normal conditions this arrangement makes a basement with its expensive foundations unnecessary. In this particular instance, however, a basement had to be provided for the gas mains associated with the exhausters and boosters and for various pumps, but even so considerable economy in height was effected. Fig. 15 illustrates the basement with the pumps.

The main switchgear comprises ten sheet-steel cubicles with mechanical remote control from a ten panel block enamelled operating switchboard built into the spaces between the pillars of the machine house wall, directly opposite the turbo generators. It is divided into two sections, arranged so that the complete plant can if necessary be run off either section alone.

Fig. 8.—Old Method—Breaking Coke Cake.

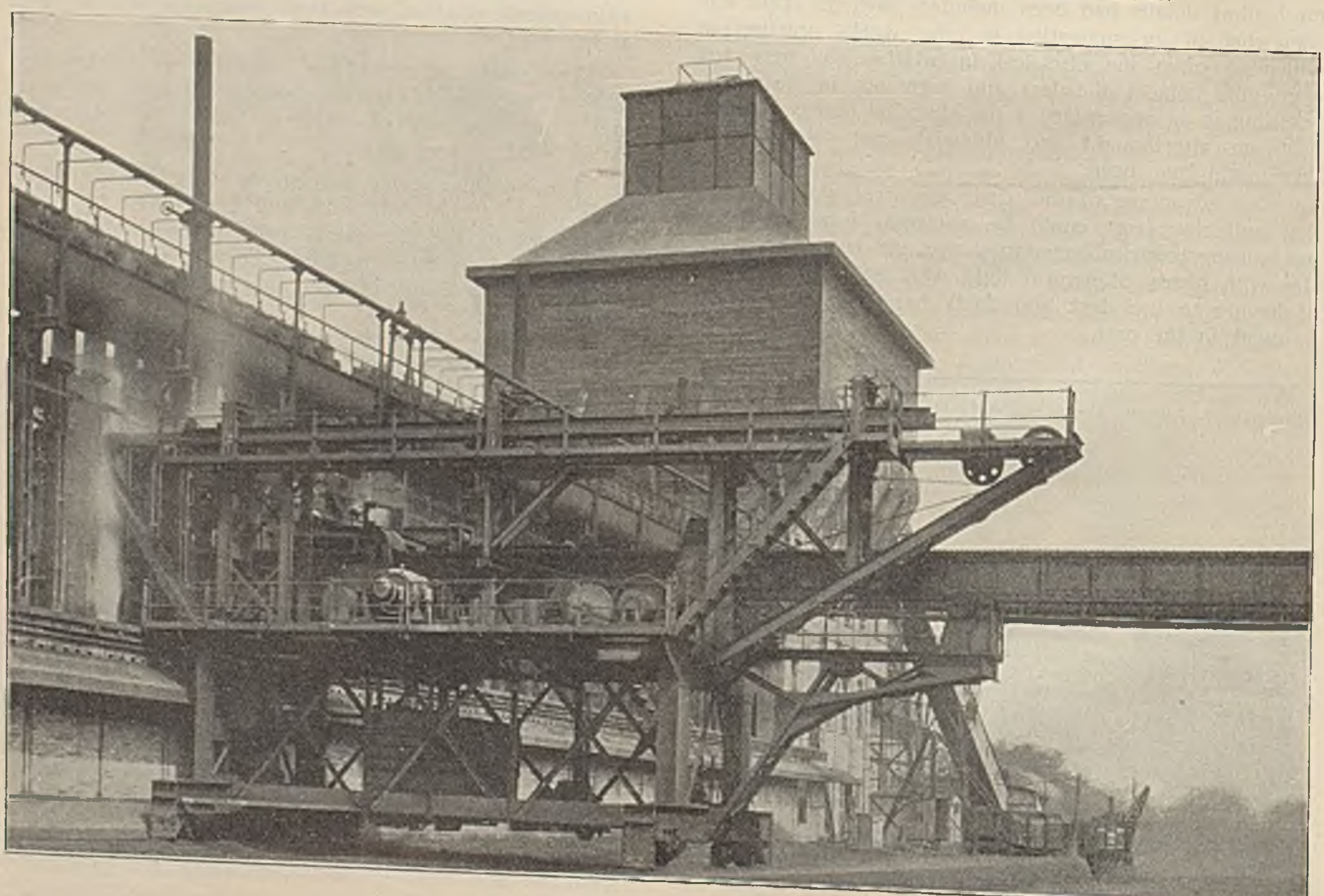


Fig. 7.—Modern Pusher Machine.

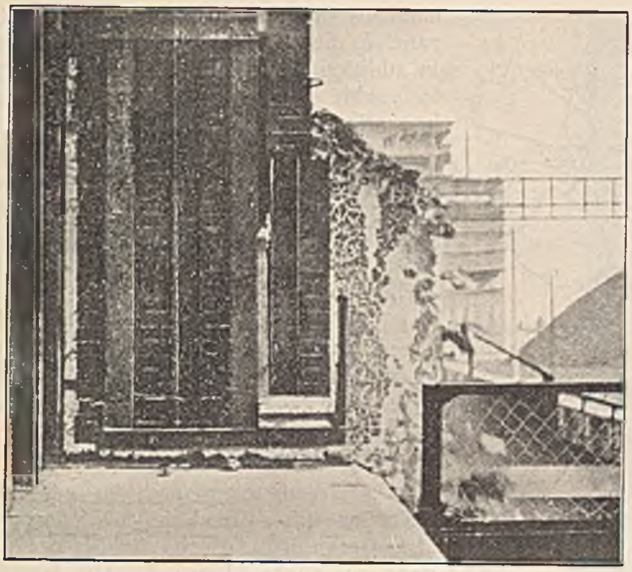


Fig. 9.—*Modern Coke Guide.*

Fig. 10.—*Old Method—Hose Quenching.*

The operating board comprises: section switch panel; two generator panels; two feeder panels, for step-up transformers for outgoing transmission lines to the Company's other establishments; two panels for a ring main for the coke oven and coal handling plant; two panels for duplicate feeders for the by-product plant; and one panel for the main feeder to the coal cleaning plant.

The cubicles themselves are located in an annexe to the power house, and there is a wide passage way between the cubicles and operating board to give access to the back of the latter on which the auxiliary wiring for instruments and protective devices is neatly and methodically arranged. It is hardly necessary to stress the advantage of this remote control arrangement as compared with the direct operated cubicle type of board in which the auxiliary wiring is located in the cubicles behind the heavy switchgear and connections.

The switchgear itself is designed on modern lines embodying all necessary instruments and safety devices. The turbo generators have Merz Price protection neutral earth switches, and field suppression device. The transformers have Merz Price protection in which the switches automatically trip when the corresponding E.H.P. switches are opened. The feeders have leakage trips. Each panel has an integrating k.w. hour meter and the transformers have separate incoming and outgoing meters, so that the whole power can be checked up and accounted for.

Mounted behind the main switchboard in the annexe are two eight-panel distribution switchboards for the by-product recovery plant, of the oil-immersed ironclad circuit breaker type : Fig. 16.

Two 800 k.v.a. main transformers are housed in separate chambers at the other end of the annexe, and the E.H.P. switchgear is in line with the main switchgear opposite the turbo exhausters. The E.H.P. switchgear, Fig. 17, is of the draw-out truck type, and comprises two transformer cubicles and two feeder cubicles, one for the colliery transmission line and the other for the loading staithes, which are about two miles distant on the banks of the Tyne, and where coal, coke, and other products are shipped.

When working in parallel with the colliery system, an independent adjustment of the power and power factor must be possible, without affecting the pressure at the coke works. For this purpose an induction regulator, Fig. 18, is interposed between the high pressure busbars and the transmission line.

The line is designed to carry 1500 k.v.a. maximum. If 1500 k.w. surplus power were available at the coke works it would have to be transmitted at about unity power factor, and for this purpose the pressure would have to be raised to approximately 6000 volts. On the other hand if there were no surplus power at Derwenthaugh, it should be possible so to raise the voltage by means of the induction regulator that lagging wattless current could be supplied to Chopwell.

Provision is also made for a limited amount of power to be transmitted from Chopwell to Derwenthaugh.

The regulator has an output of 113 k.v.a. and permits of a voltage adjustment of 450 volts up or down, making a total possible variation of 900 volts. The regulator is

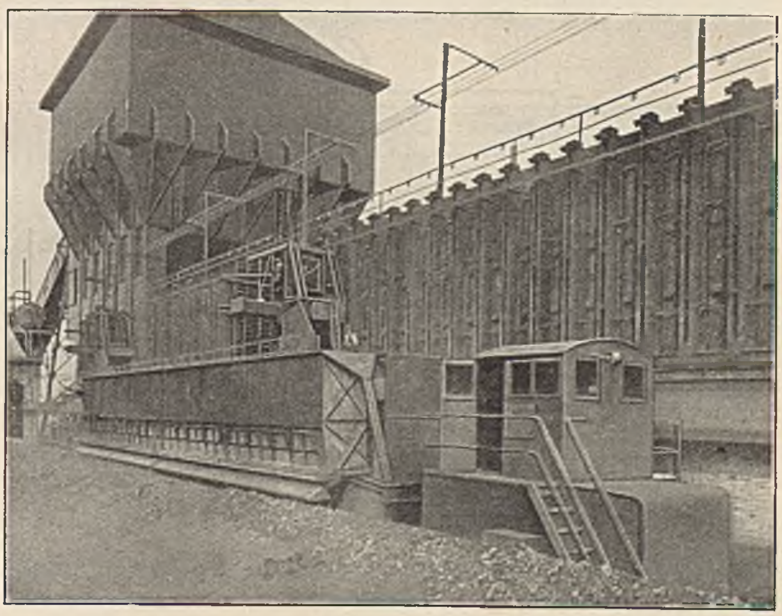


Fig. 11.—*Modern Quenching Car and Locomotive.*

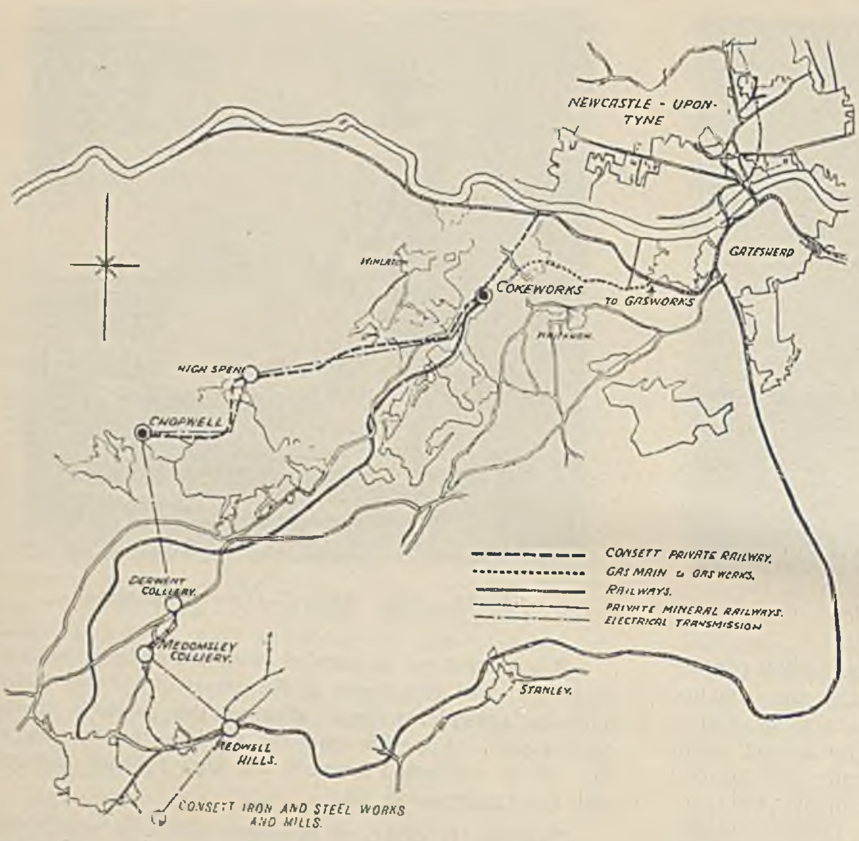


Fig. 12.—Map shewing the Gas and Electric Mains.

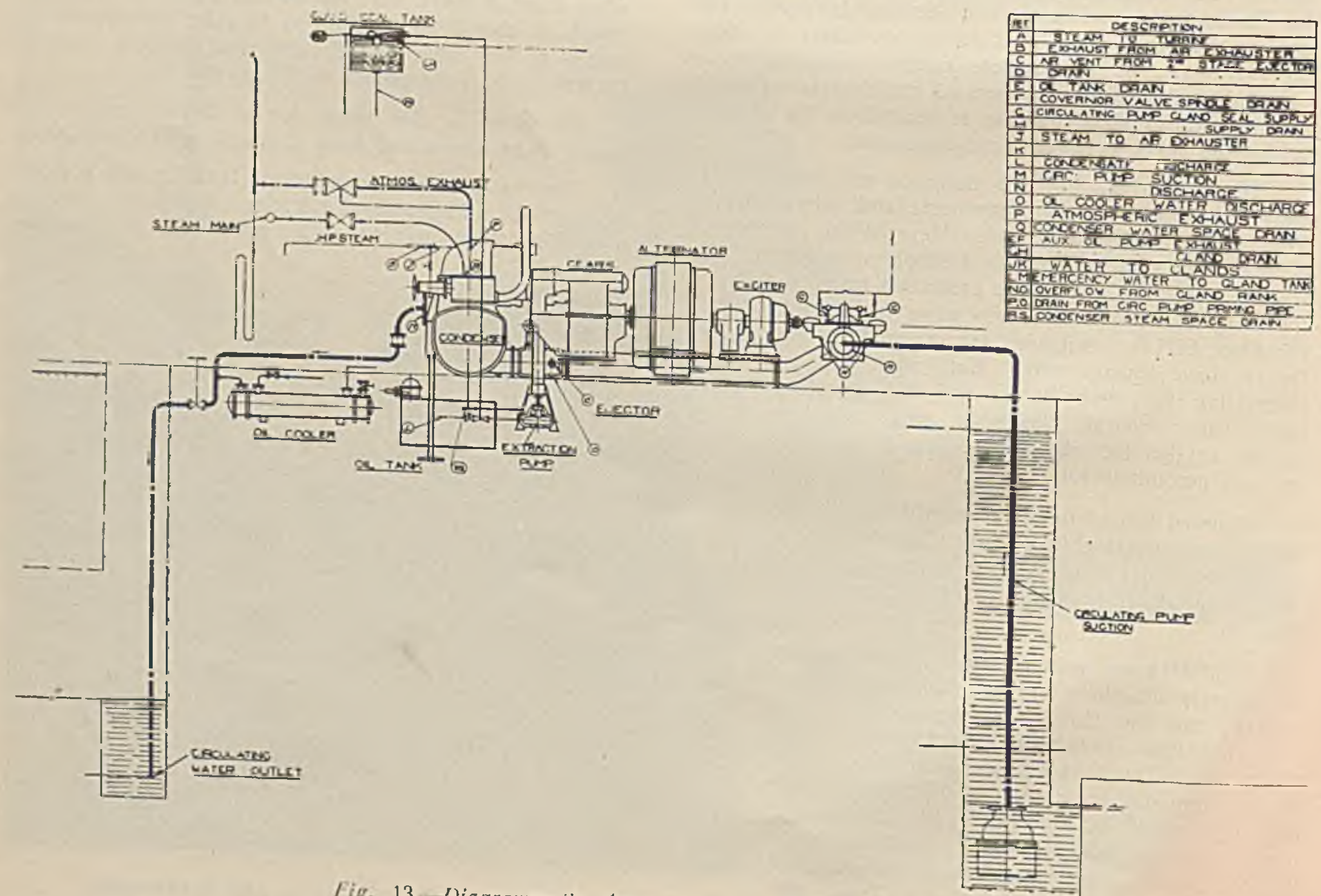
manually controlled from a dummy panel in line with the draw-out trucks. In addition there is an isolating cubicle to enable the induction regulator to be entirely isolated.

The annexe also contains two 60 k.v.a. lighting transformers and a main lighting switchboard from which the lighting feeders to the various departments and the outside lights are controlled.

The space under the switchboard annexe is reserved for cables and is of sufficient height for comfortable head room.

Essential Regularity of Works Process.

As already mentioned, for efficient operation of a modern coke works, strict regularity of all major operations has to be observed. The layout of the distribution mains received very careful consideration to ensure continuity of supply under practically all conditions and yet to enable all sections to be shut down for examination and maintenance. Fig. 19 is the key diagram of the distribution system. For the by-product plant, practically all machines are in duplicate so that two separate main feeders and distribution systems were laid down, one of each pair of machines being supplied from each system. In the case of certain



REF	DESCRIPTION
A	STEAM TO TURBINE
B	EXHAUST FROM AIR EXHAUSTER
C	AIR VENT FROM 2ND STAGE EJECTOR
D	DRAIN
E	OIL TANK DRAIN
F	GOVERNOR VALVE SPINDLE DRAIN
G	CIRCULATING PUMP GLAND SEAL SUPPLY
H	SUPPLY DRAIN
J	STEAM TO AIR EXHAUSTER
K	
L	CONDENSATE DISCHARGE
M	CIRC. PUMP SUCTION
N	DISCHARGE
O	OIL COOLER WATER DISCHARGE
P	ATMOSPHERIC EXHAUST
Q	CONDENSER WATER SPACE DRAIN
EF	AUX. OIL PUMP EXHAUST
GH	GLAND DRAIN
JK	WATER TO GLANDS
LM	EMERGENCY WATER TO GLAND TANK
NO	OVERFLOW FROM GLAND TANK
PQ	DRAIN FROM CIRC. PUMP PRIMING PIPE
RS	CONDENSER STEAM SPACE DRAIN

Fig. 13.—Diagrammatic Arrangement of the Turbo Generator.

machines, this scheme could not be carried through and these are fed from a sub-distribution board with duplicate feeds and a change-over switch.

For the coke oven machinery and coal handling plant in which duplication of machines is exceptional, a ring main was arranged. One feeder supplies the coke oven machinery through a distribution switchboard under the large coal bunker; the other feeder supplies the coal handling and crushing plant through a distribution board in the crusher house, and the ring is completed by an interconnection between the two distribution boards. Fig. 20 illustrates the crusher house switchboard. The feeders were dimensioned so that both crushers, each with a 200 h.p. motor, as well as the coal handling and the coke oven machines could all be operated simultaneously at full load; it was further stipulated that with either feeder out of commission, one crusher and the rest of the machinery could be supplied without overloading the cables.

The coal cleaning plant has a separate main feeder from one side of the main switchboard, and an auxiliary connection from the coal handling distribution board which is fed from the other side of the main switchboard. The cleaning plant is shewn in Fig. 21.

Feeders and Cables.

The main power feeders and distribution cables are three-core paper-insulated lead-covered and armoured cables, laid underground or clamped to the buildings. Individual motors are fed with three-core V.I.R. insulated and armoured cables. Wiped joints and substantial armour clamping and bonding to all apparatus and motors ensure continuity of metallic covering and earthing circuits, while duplicate earthplates secure facilities for testing and maintenance.

For the outside lighting and distribution for lighting of separate buildings and structures, there is an overhead pole distribution system. The interior wiring (Fig. 22) has been carried out with two-core and three-core bitumen insulated single-wire armoured cables with water-tight mining type joint boxes.

Lighting.

A high degree of illumination has been provided and fittings with brass glands, and in addition facilities have been furnished for an ample number of portable inspection lamps by the installation of over 100 plug connectors. For lighting the yards and sidings there are 85 lamps of 500 watts to 1000 watts on 30-foot poles or suspended from brackets. Special reflectors were selected to obtain even illumination, and angle fittings are installed for flood lighting the oven battery sides and also, where necessary, for preventing glare along the adjacent high road.

Motor Control.

Details of the various motors and method of control were published last year, and it is

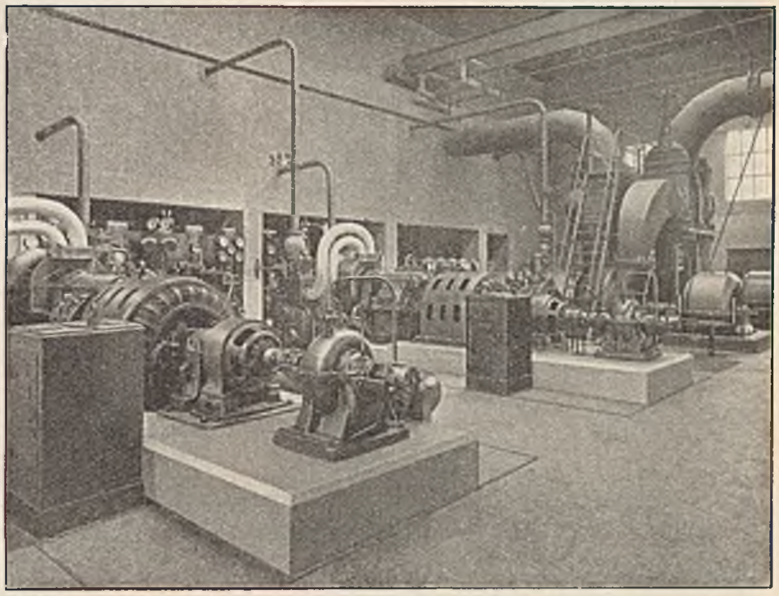


Fig. 14.—Turbo Generating Plant.

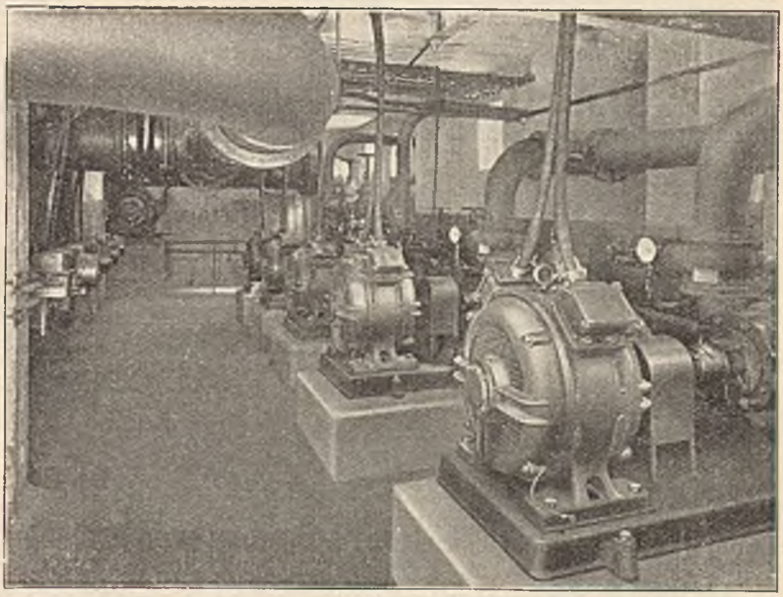


Fig. 15.—Pumps in the Engine Room Basement.

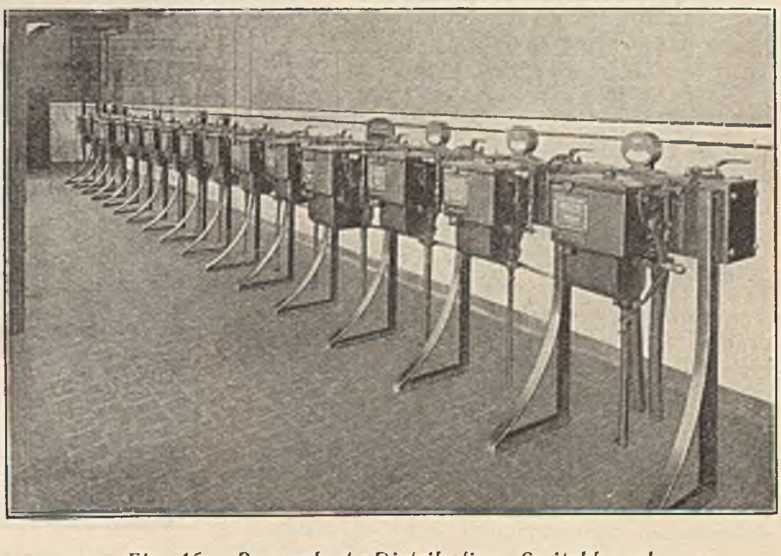


Fig. 16.—By-product Distribution Switchboard.

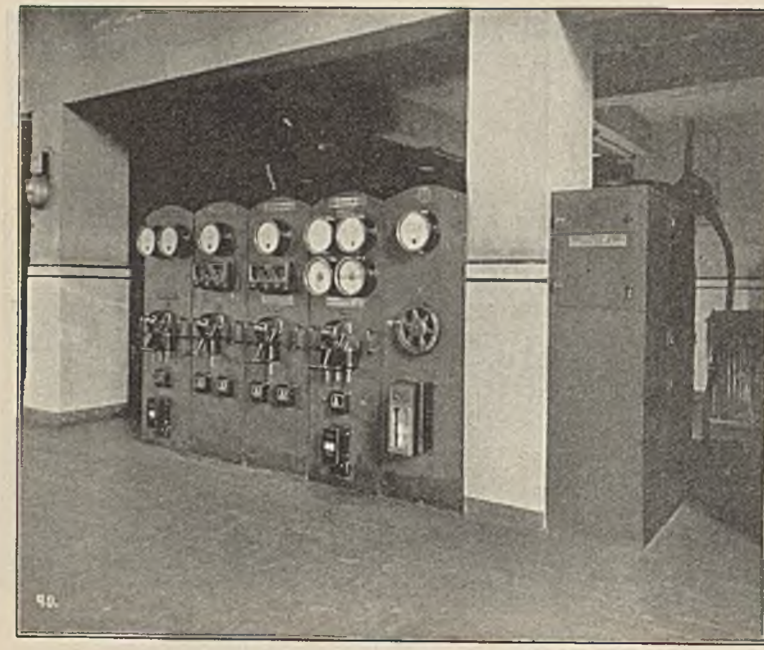


Fig. 17.—*The E.H.P. Switchboard.*

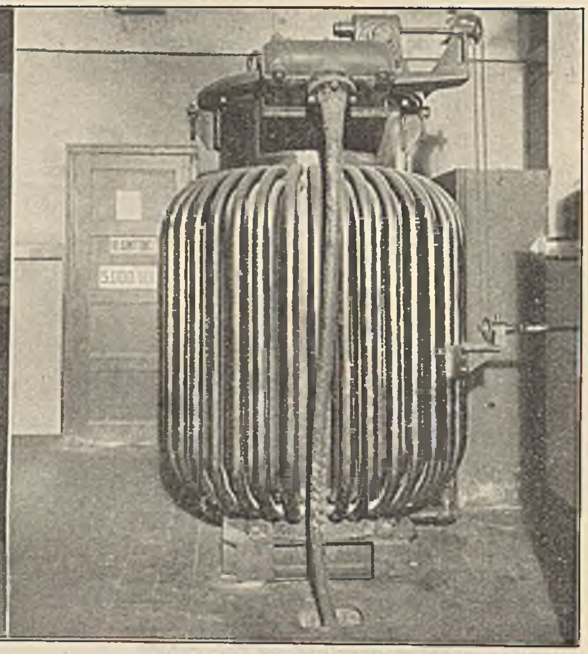


Fig. 18.—*Induction Regulator.*

therefore only necessary to emphasise the departure from previously accepted practice in the entire elimination of direct current motors from coke oven machinery, and the practically universal adoption of high torque squirrel-cage motors throughout (even for those applications where the use of direct current or three-phase slipring motors was previously considered essential).

Such departures from squirrel-cage to slipring which have been made were due to considerations of line voltage drop with starting peaks rather than to the mechanical inability of the motor to suit the application.

The squirrel-cage motors in use on the plant are of the high torque, high efficency type, specially designed to meet the most exacting conditions. The stator

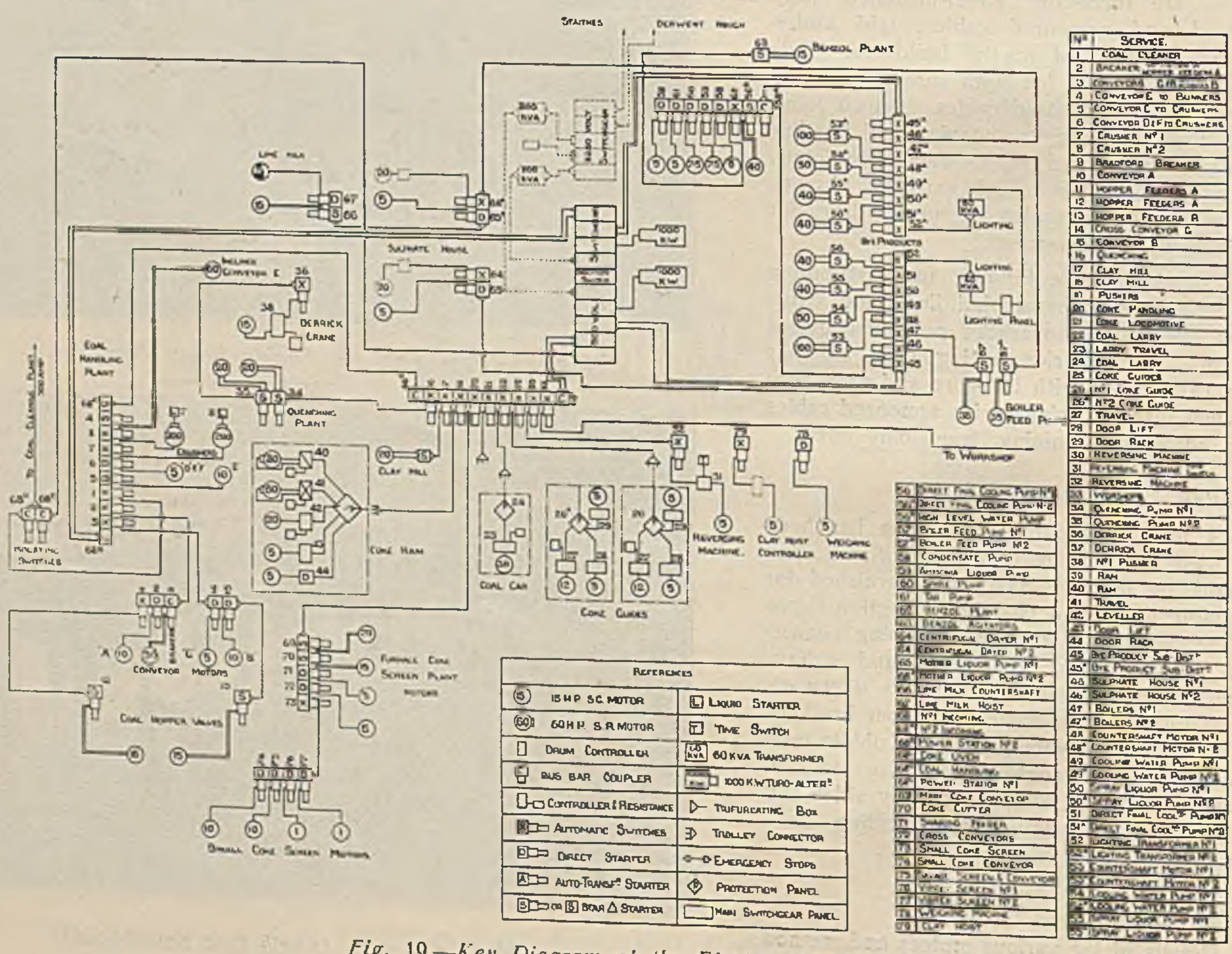


Fig. 19.—*Key Diagram of the Electrical Plant.*

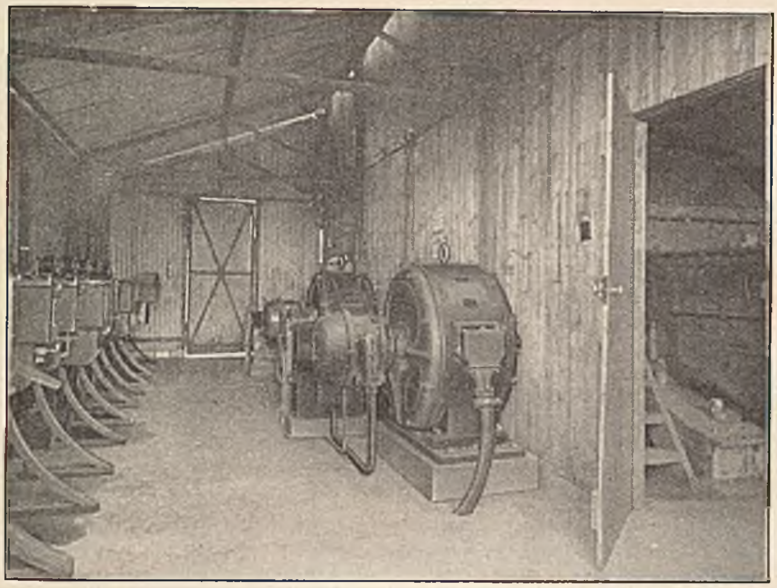


Fig. 20.—Crusher House Switchboard and Hammer Mill drive.

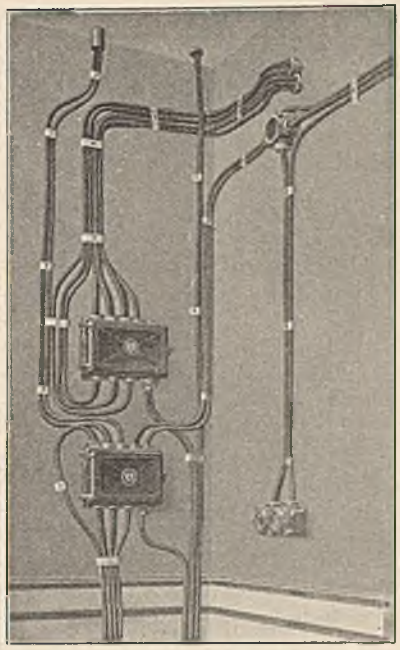


Fig. 22.—A Section of the Armoured Wiring System.

of this machine follows standard construction; the rotor, however, is of the double wound solid bar type, in the core of which is embedded two windings spaced in special relation to the core teeth and of varied resistance and reactance so that at the moment of starting i.e., at maximum rotor volts and frequency, one winding takes dominance and provides a starting torque nearly equivalent to that of a slipring rotor with resistance in circuit.

When full speed is reached (i.e. minimum rotor volts and frequency) the second winding becomes preponderant giving a characteristic similar to a slipring machine with short circuited sliprings, i.e., a condition of minimum slip, and therefore maximum efficiency. There is no switching of any description from one winding to the other, and the change takes place gradually as the motor speeds up, with no variation in acceleration against a constant load.

Three methods of starting these motors are employed. Generally up to 15 h.p. without speed control, the motors are direct started.

From 15 h.p. upwards, again where no speed control is required, the motors are either star-delta started or started with a single step of resistance in the stator circuit, depending upon the torque requirement of the equipment to be started.

Irrespective of power, where control is required during starting or a certain amount of low speed running is necessary, the motors are controlled exactly like a slipring motor, with the exception that the resistance instead of being inserted in the rotor circuit is introduced into the stator circuit.

A detailed description of this type of motor with illustrations and graphs of performance and characteristics may be found in a paper by H. T. Gregory on "Three-phase Induction Motors and their Control Systems," published in *The Mining Electrical Engineer*, Vol. X., No. 106 July, 1929, pp. 22 *et seq.*

Fig 21.—Automatic Control for Coal Cleaning Plant.

The experience in service of this type of motor has entirely justified its adoption. There are about 100 motors (originally about 90, aggregating over 2000 b.h.p., varying from ¼ b.h.p. to 200 b.h.p. and the various applications are extremely diverse. It was therefore a matter of considerable difficulty to avoid an overwhelming number of different types. A great deal of care was expended and no trouble spared in the attempt to duplicate motors. Wherever possible, and where absolute duplication was not practicable the aim was to utilise the same frame sizes so that mechanical parts such as bearing brackets and bearings were interchangeable. By this means the actual number of spares carried could be reduced to a minimum and the satisfying feeling of security in case of breakdown was obtained; a condition of mind readily understood by every practical electrical engineer and works manager connected with the operation of plant which must under all circumstances continue to work uninterruptedly to schedule night and day, year in and year out.

TABLE IV.

DERWENTHAUGH COKE WORKS. EXTRACT FROM DAILY LOG.

UNITS PER HOUR.

	1	2	3	4	5	6	7	8
Date and hour. 1930.	*Coal Cleaning.*	*Coal Handling.*	*Coke Ovens.*	*By-Products.*	*Total* 1—4	*Trans-formed.*	*Total used.*	*Generated.*
Oct. 13—5 p.m.	4	—	98	277	379	300	679	686
6 „	—	—	47	282	329	225	554	566
7 „	—	—	61	301	362	215	577	578
8 „	—	—	47	304	351	212	563	582
9 „	—	—	47	291	338	227	565	574
10 „	—	—	56	300	356	257	613	621
11 „	99	65	48	295	507	193	700	715
12 „	133	85	53	310	581	177	758	777
Oct. 14—1 a.m.	135	84	58	311	588	179	767	775
2 „	123	52	39	300	514	318	832	843
3 „	125	83	56	299	563	276	839	852
4 „	128	81	51	297	557	300	857	868
5 „	128	78	48	302	556	292	848	860
6 „	128	79	54	291	552	294	846	877
7 „	123	66	54	274	517	311	828	835
8 „	126	80	59	253	518	287	805	810
9 „	129	81	94	264	568	269	837	855
10 „	131	83	74	268	556	334	890	905
11 „	124	80	95	261	560	275	835	850
12 „	134	82	95	269	580	313	893	895
1 p.m.	125	78	81	250	534	292	826	835
2 „	39	21	77	248	385	473	858	871
3 „	—	—	82	262	344	485	829	838
4 „	—	—	92	269	361	437	798	808
Total	1934	1178	1566	6778	11456	6941	18397	18676

	Total.	*Average. Units per hr.*	*No. hrs.*
Coal Cleaning	1934	121 ×	16
Coal Handling	1178	74 ×	16
Coke Ovens	1566	65 ×	24
By-Products	6778	282 ×	24
	11456 =	542 ×	16
		347 ×	8
		477 ×	24

Transformed	6941	
Total	18397	
Difference	279	
Generated	18676	778 × 24

As, with few exceptions, machines are in duplicate and those about the coke ovens are very intermittent in their duty, there is a fairly high diversity factor, i.e., the ratio between motor power installed and average power. The figures given in Table IV. were taken at random from daily log sheets.

(*To be continued.*)

MIDLAND BRANCH.

The Meeting of the Midland Branch on November 29th was held at the Mansfield Technical Institute. Mr. C. D. Wilkinson, Branch President, occupied the chair. After the minutes of previous meetings had been adopted, it was decided to fix the visit to Derby Cables Ltd. to take place on Saturday, January 17th, 1931, at 3 p.m. The firm had kindly promised to have the Works in full operation on the occasion of this visit.

It was also arranged for the next meeting of the Branch to be held on Saturday, December 13th at the Nottingham University College, when Dr. H. Cotton, M.B.E., D.Sc., would give the first of the series of five lectures on "Electrical Engineering as applied to Mining Practice," as arranged by the Branch Council.

A new member was elected: Mr. Geo. F. Cadden, Chief draughtsman and cable designer to Derby Cables Ltd., Alfreton Road, Derby.

The President, Mr. C. D. Wilkinson, then delivered his inaugural address as follows.

Presidential Address.

The Parallel Operation of Alternators.

C. D. WILKINSON.

It is not proposed to make any general survey of present practice or of the work of the Association, as those subjects are often dealt with in *The Mining Electrical Engineer,* but to deal with a subject which has not often appeared in the papers of the Association, possibly because most members are very familiar with it. The subject chosen is the Parallel Operation of Alternators, over ground with which you are all familiar.

When it is desired to parallel d.c. generators it is only necessary to ensure that the polarity of the respective coupled terminals of the machines are similar and the e.m.f. of the incoming machine is equal to that of the bars; after the incoming machine has been connected to the bars, it can be made to take any desired share of the load by the adjustment of its excitation.

The paralleling of an alternator is more complicated since in addition to equality of voltage there must also be equality of phase and frequency.

Before attempting to parallel a new machine it is necessary to check its phase rotation and to ensure that this is similar to that of the other machines. This can be checked as shewn in Fig. 1, which shews the three-phase case.

It will be seen that one phase of the machine is linked through to the bars whilst voltmeters are interposed between the other two phases. If both voltmeter needles rise and fall together the phase rotation is correct, but if the needles rise and fall alternately the phase rotation is wrong, and any two of the new machine connections must be interchanged. It is important to remember that the voltmeters will be subjected to twice the machine pressure and should therefore be chosen accordingly.

Another method often used is to run up an induction motor from the bars and then from the new machine, connecting terminals A, B, and C of the motor, to the similarly marked phases of the bus-bars and the new machine respectively.

If the direction of rotation is the same in each case then the phase sequence is correct, but if the motor runs in opposite directions then two leads of the new machine must be interchanged.

Having checked the phase rotation, to connect an alternator B in parallel with another one A, already on the bars, the frequency and voltage of the former must be identical with that of the latter, and must also have the same instantaneous value of phase.

In order to ascertain when these conditions obtain, synchronising lamps are connected as shewn in Fig. 2.

If machine A is on the bars and machine B unexcited, a current will pass round the path abLBLcdA and cause the lamps to glow. If machine B is now excited and its voltage adjusted to that of the bars, its e.m.f. will alternately oppose and assist that of the busbar voltage in the lamp circuit. If the machines are not exactly in step the pressure across the lamps will be the varying resultant of the two alternator pressures and the lamps will pass through varying degrees of brilliance. The changes in the resultant voltage will be as shewn in Fig. 3.

When the machines are absolutely out of phase, the pressure across the lamps will be twice that of either machine, and the lamps will attain maximum brilliance.

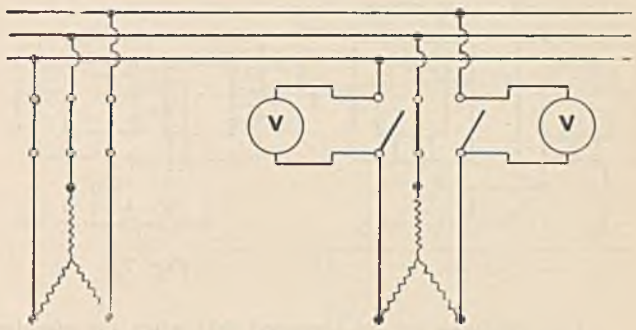


Fig. 1.

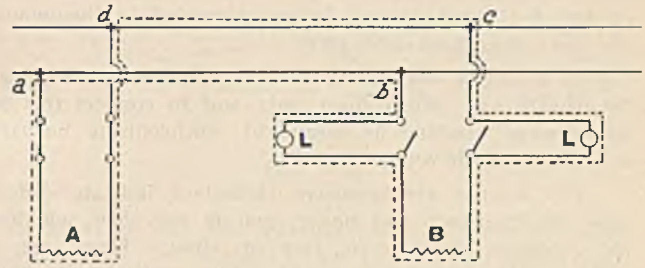


Fig. 2.

When the machine B has, by careful adjustment of its speed, been brought into step with A, the two e.m.f.'s acting on the lamp circuit will be opposition and the lamps dark. The switch of machine B should be closed at this instant and the machines will then be in parallel, and can be made to share load as described later.

The single phase case has been shewn, but the procedure would be the same for polyphase machines. Fig. 4 shews the connections for the dark synchronising of polyphase machines and Fig. 5 shews the lamp leads transposed to give bright synchronising.

The latter is the better method since it is easier to determine the instant of maximum brilliance than the centre of a dark interval.

The connection of synchronising lamps across the switch contacts is only possible for low voltage machines, and if it desired to use lamps for high voltage machines they must be inserted in a circuit formed by connecting in series the secondaries of two small potential transformers as shewn in Fig. 6.

Instead of two transformers a single one which employs three windings as shewn in Fig. 7 may be used.

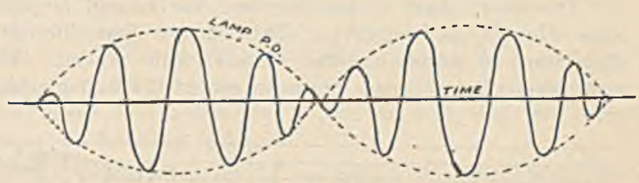


Fig. 3.

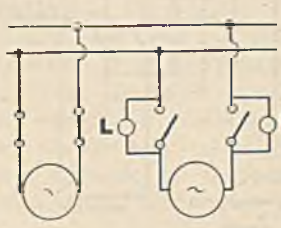


Fig. 4.

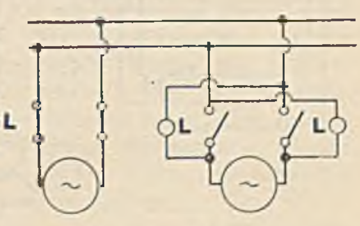


Fig. 5.

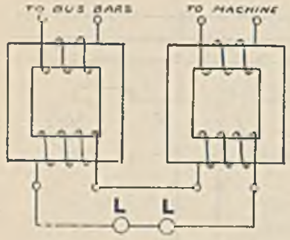


Fig. 6.

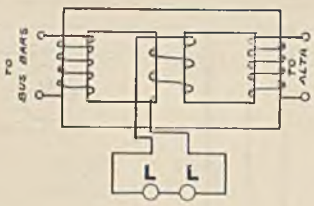


Fig. 7.

The windings are so arranged that when the machine and busbar e.m.f.'s are in step, the maximum flux links with winding S, generating the maximum voltage in it, and the synchronising lamps connected to this winding have maximum brilliance.

In a station containing several machines it is usual to provide one synchroniser only and to connect this to any desired machine by means of synchronising busbars and plugs as shewn in Fig. 8.

The simple synchronisers described indicate differences in frequency and phase, but do not shew whether the incoming machine is fast or slow. There are a number of commercial synchroscopes which give this advantage.

If two alternators have been perfectly synchronised and have exactly the same e.m.f. their e.m.f.'s are in phase apposition with regard to the local circuit formed by their two armatures and there is no current or power circulating in this circuit.

If one generator falls a little behind the other in phase, the two e.m.f.'s are no longer in opposition in the local circuit so that a resultant voltage is set up. This resultant voltage sets up a current, known as the synchronising current, in the local circuit and, since the synchronous reactance is large compared with the resistance, this current lags almost 90 degs. behind the resultant voltage. A synchronising force is brought into play which tends to keep the two machines in step.

The vector diagram is shewn in Fig. 9. Ea and Eb represent the alternator voltages, Eb having fallen behind its ideal position by the angle θ. The resultant voltage is shewn by Er which is almost in quadrature with both generator e.m.f.'s.

The synchronising current is shewn by Is and this lags almost 90 degs. behind Er. Is is therefore almost in phase with Ea, the e.m.f. of the leading generator, and this machine generates a power E_A Is Cos Ø, whilst the other machine generates a power E_B Is Cos $Ø_2$.

The first power is positive and the second negative since Cos $Ø_2$ is negative. This means that the first alternator is supplying the second with power. The generation of this power tends to retard the first machine

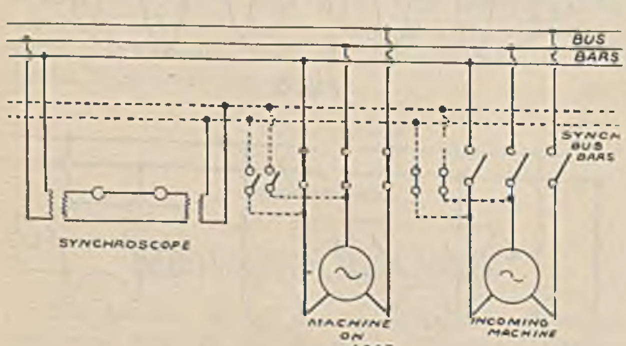


Fig. 8.

and the receipt of the power tends to accelerate the second machine, the nett result being to decrease the difference in phase between the machines and to keep them in step.

The power thus interchanged is known as the synchronising power and, by reference to Fig. 9, an approximation for its value can be made. E_A and E_B are the equal generator voltages and if the angle θ by which the machine B has dropped back from its ideal position, be measured in radians, the resultant voltage $E_R = \theta E_A$ (approx.). Since E_R is practically in quadrature with E_A, and Is in quadrature with E_R, it follows that Is and E_A are practically in phase.

Assuming the synchronous reactance of the two machines to be X, then the approximation for the synchronising power is

$$E_A \text{ Is} = \frac{\theta E_A^2}{X}, \quad \text{since Is} = \frac{E_R}{X}, \quad \text{and } E_R = \theta E_A.$$

In this expression armature resistance is neglected. For the three-phase case the synchronising power becomes

$$\frac{3\theta E_A^2}{X}.$$

The above calculations require modification if armature resistance and reactance are taken into account, but serve to shew what happens when there is a slight difference in phase between the two machines.

The synchronising power produces a synchronising torque which tends to return the machines to the stable condition.

Considering the case of two machines perfectly in phase but having an inequality of voltage, then if E_A be the greater we have a resultant voltage E_R in phase with E_A (Fig. 10).

The synchronising current Is lags practically 90 degs. behind E_A so that the synchronising power, E_A Is Cos Ø, is small.

The lagging current exerts a demagnetising armature reaction on machine A and tends to lower its voltage whilst machine B takes a leading current which gives rise to a magnetising armature reaction and tends to raise its voltage. The total result is therefore a tendency to equalise the voltages.

The synchronising power supplied by machine A also tends to retard its phase, whilst machine B which receives the power tends to advance in phase, so that the new conditions shewn in Fig. 11 will result. A small shift in phase of either machine results in a large alteration of the phase of the resultant voltage E_R and of the synchronising current which is in quadrature with E_R, and also results in the rapid reversal of direction of flow of the synchronising power. Although the tendency of this action is to bring the machines once more into phase, inequalities of voltage should be avoided since they give rise to synchronising currents with a large wattless component.

The division of true load between two alternators is entirely dependent upon the power input to the respective prime movers. Unlike d.c. machines load sharing cannot be carried out by varying the excitation. Variation of the excitation will alter the k.v.a. output but not the true power, or k.w. output. Increasing the excitation alters the wattless component and, in consequence, the power factor.

An increase in the power input to the prime mover, i.e., (admitting more steam or gas) of one alternator makes that machine take a larger share of the load. The power factors of the machine will also have a new value, that of the machine with the increased input being improved.

If two machines are operating with equal true power loads and an increase is made in the excitation of one machine, then the phase of the resultant voltage E_R in the local circuit will be the same as that of the machine witch the higher excitation.

As previously shewn the heavily excited machine has a demagnetising armature reaction, and the more lightly excited machine has a magnetising reaction.

The wattless component of the total load is unequally shared; the machine with the stronger excitation taking the greater proportion. If the difference in excitation be made sufficiently large, one of the machines—that with the weaker excitation—will operate at a leading power factor.

If two machines operating in parallel have different wave forms there will always be a resultant voltage and therefore circulating currents round the local circuit, despite equality of phase and virtual voltage.

The fundamental components of the e.m.f.'s may cancel out, but the harmonics will give rise to the circulating currents mentioned. In consequence, only machines of a similar wave form, which should approximate very closely to the true sine wave, should be used in parallel.

If a number of machines are operating in parallel it is necessary to increase the excitation of all the machines when it is desired to raise the busbar voltage. Increasing the excitation of an individual machine causes it to take more wattless current and reduces its power factor.

To raise the busbar frequency the speed of all the prime movers must be increased. Increase in the speed of one machine merely causes that machine to increase its individual load and to lighten the load on the other machines.

When a machine has to be removed from the bars its speed must be reduced until its k.w. load is floated off. The wattless load must than be removed by reducing the excitation and finally the machine disconnected from the bars.

The interconnection of power stations is now becoming general and is really an extension of the parallel running of alternators.

Differences in station pressure, frequency, or even number of phases are no obstacle to the linking up of stations since these differences may be overcome by transformers, frequency changers, and phase changing transformers.

The parallel operation of distant stations is a subject which needs treatment in a separate paper: it may, however, be mentioned here that if the phase and value of the voltages at the two ends of the interconnecting line are identical, no current will flow in the interconnecting line.

It is therefore necessary to displace the phase of the voltage at one station to obtain transmission of power, and also to raise the voltage to overcome the impedance drop of the interconnector.

Mr. WILKINSON concluded his address with the hope that the coming session would be remarkable for well attended meetings, and that every member would

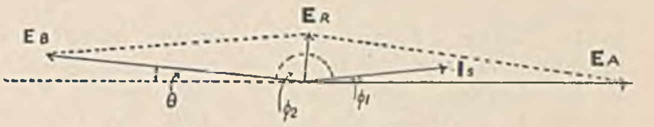


Fig. 9.

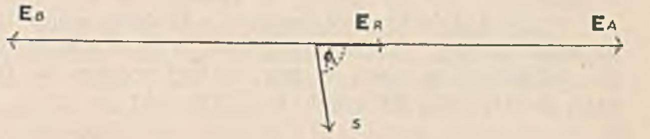


Fig. 10.

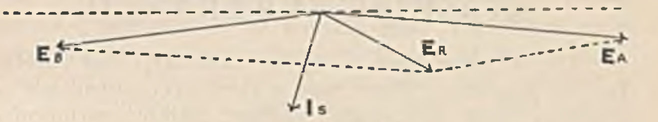


Fig. 11.

endeavour to take full advantage of the opportunity of hearing such an authority as Dr. Cotton lecture on Mining Electrical Engineering. They were very fortunate in being able to secure the services of Dr. Cotton.

Dr. H. COTTON, in proposing a vote of thanks to the President for his address, said they were not supposed to contribute any discussion to a presidential address, but he thought Mr. Wilkinson's address would be a very useful introduction to the lecture on electrical engineering which they were to consider during the coming session. The sole aim of his (the speaker's) coming lectures was to instil the principles of electrical engineering into the younger members of the Association.

With regard to the fee which had been arranged for the course of lectures; he did not feel inclined to make any personal gain and therefore intended to use this amount to provide prizes for the three members who gave the best results at the forthcoming Association Examinations.

Mr. R. WILSON said it was his privilege to second the vote of thanks proposed by Dr. Cotton. He had had the honour of occupying the position now held by Mr. Wilkinson on three separate occasions and could therefore claim to know something about it, and he would like to congratulate Mr. Wilkinson on having had the courage to depart from the beaten track. He had tried it himself on one occasion, and he really felt amply repaid for the trouble he had taken. He was quite certain that Mr. Wilkinson would feel well repaid for preparing an address of the description they had heard that afternoon in the interest that had been displayed by those present.

He would also whilst seconding this vote of thanks like to propose one to Dr. Cotton for the very generous attitude he had adopted with regard to his fee for the course of lectures. As a member of the Branch Council and also of the Advisory Committee of the University College between which parties the lectures had been arranged, it was certainly the idea that the fee would be some acknowledgement of the trouble Dr. Cotton was taking in giving the course. It was very generous on the part of Dr. Cotton to offer the amount for the presentation of prizes.

Mr. WILKINSON, in responding to the vote of thanks passed, said he had very great pleasure in seconding the vote of thanks proposed by Mr. Wilson to Dr. Cotton. It was a very generous gesture, and to those who knew him it was one which came naturally to Dr. Cotton. The giving of these lectures would trespass on his time, which was already fully occupied. He was sure all present would wish to join in thanking him for his proposal.

Mr. WILSON brought forward a problem which led to some amount of discussion, but as this was to be the subject of a paper at one of the meetings in the near future, full discussion was left over.

AYRSHIRE SUB-BRANCH.

The Ayrshire Branch met on Saturday, 22nd November, at Annbank. There was a very large attendance of members, and also many visitors mainly machinemen and other colliery workers interested.

Mr. R. L. ANGUS, of Ladykirk, Monkton, presided, and at the outset referred particularly, for the benefit of the non-member visitors, to the Association of Mining Electrical Engineers. The Association was founded 21 years ago and consisted now of 10 Branches and 7 Sub-Branches. The Ayrshire Sub-Branch was formed in January, 1920, with 23 members. The number of members gradually increased until 1926 when the membership was 105. Since then, unfortunately, many Ayrshire members had left the county, some having gone to other parts of the country while others had gone abroad, to Canada, South America, and India. The present strength of the Branch was 57, a figure which it had maintained for the past two years.

Meetings were held every month from September till April and papers of various kinds were read, all pertaining to electricity and its application above and below ground, and in Summer a visit was usually paid to a colliery or other place where the electrical equipment was particularly worthy of inspection.

Special meetings, such as the present one, were organised by the Branch Council for the benefit of machinemen and others using electrical appliances underground, and meetings similar to that had been held during the past three years in Cumnock and Dreghorn.

Mr. Alex. McPhail was to have read them a paper that day but unfortunately he was confined to bed with a chill. His place would be taken by Mr. James R. Laird, of the West of Scotland Branch.

General Power Generation Problems.

Short Circuits.

JAMES R. LAIRD.

GENERAL PROBLEMS.

Those who think Engineering is not worth following as a profession have not been smitten with its fascination, its problems, the possibilities and the need for research and the natural pride of accomplishing things and solving the problems. They miss that feeling of satisfaction, something attempted, something done, something handed on to posterity.

Our economic position in the coalfield to-day is that coal cannot compete with water power on the Continent. It is having a hard task against oil; a pound of oil can evaporate 50% more water than a pound of coal. There are seventy-four 13¼ million h.p. water schemes in Europe; there is 444,000,000 h.p. of water power available in the world at a reasonable cost per h.p. Of this total only 40,000,000 h.p. is being used.

We are faced with the fact that one pound of coal contains as many thermal units when converted to foot-lbs. as 40 tons of water falling one hundred feet. The greatest efficiency that is at present obtained by the most economical use of coal to produce electricity is 24% so that even if a hydro station costs three times as much as a coal, steam or gas oil station costs, it is still an economic proposition.

We had our James Watt who gave us the steam engine and condenser, and 170 years after his life's work we can only utilise one-fourth of the energy contained in coal as useful units of electricity. After we have the electrical units we can only use about 5% of this energy when converting it to light and this is the reason we form ourselves into an Association, to dig deeply into the laws governing these phenomena. By adopting water power and generating electricity, 160 million tons of coal is saved per annum. If the 444 million horse power becomes harnessed, this country may be the tail end of a five million volt system from the Continent.

How to use our coal to the fullest economic advantage is our heritage. To win and export our coal economically is our only means of competing with water power and oil in other countries. A steel company in Norway gets its hydro-electric supply at its works at the rate of 16 units for a penny. There is only some 250,000 k.w. of water power available in this country at a cost of £50 per k.w. The world's output of coal in 1927 was 1,276,000,000 tons and the visible balance is estimated to last 4000 years. How to get 70% efficiency equal to a hydro scheme is up to us.

To use coal economically we must find out where the 75% is lost and to do this we must arm ourselves with all the known laws and methods at present in use, which means an early part of our lives must be spent in assiduous study of the sciences. We know that a boiler is designed to evaporate water and raise the steam to a suitable pressure. The coal has to be brought to the boilers and it has to be consumed under the boilers, getting the proper supply of air for its complete combustion and, finally, the residue removed from the grate and we have only evaporated 8 lbs of water per pound of coal. We also find that the gases going up the chimney have still a fairly high temperature though we have saved some of the heat by catching it in the feed water. We also use the hot gases to pre-heat the air for combustion. We carry the steam to the prime mover, expand it down till it has all its force above atmosphere and, finally condense it to get the advantage of atmospheric pressure. The water is then passed to the hot well and returned to the boiler and, despite the care and painstaking carefulness, we have only got one-fourth of the original value of the fuel in useful work on our switchboard busbars.

Let us look at the hydro-electric scheme: we find a lake on a high mountain, snow melting on the mountain sides in addition to rain-fall. The lake is tapped, a pipe line run down to the power station where the waters sattic head is converted into power at the busbars up to 500,000 volts, ready for an 800 miles transmission at an efficiency of almost 80%. A pound of coal of 14,000 B.T.U. value, converted to foot-lbs. is equal to 48 tons of water falling through 100 feet. The hydro engineer is entitled on an economic basis to spend three times the amount on his station that the steam station engineer does, because steam generation of power is uneconomic compared with hydro generation. With the hydro station there are no chimneys or products of combustion to be got rid of. Steam has been generated at 1500 lbs. pressure. Mercury has been tried instead of water, using a completely closed cycle. Turbines of 250,000 k.w. with several stages even in separate machines on their own shafts with steam carried through the sets, and with superheating between the sets have been tried.

SHORT CIRCUITS.

The subject of short circuits to earth was to have been dealt with by Mr. McPhail; the present speaker will only give a few instances of short circuits in general. A motor with its rotating part fixed so that it cannot revolve is a short circuit. The maximum extent of the short circuit current is only limited by the short circuit value of the generator feeding into it. If there was no circuit breaker or fuse the smaller cables, or probably the windings of the motor, would eventually fuse. The solder used in joining up the end connection would fuse and the joints be unsweated.

Motors in a constant current system can limit and carry this constant current without the current value rising on short circuit. With a constant definite supply pressure the current value will continue to rise on short circuit whilst the pressure supply is maintained, so that the more ponderous the centre power supply, the more destructive will be the effect of the short circuit. An arc cannot live in a magnetic field, so one successful method of opening a circuit whose current has risen to an abnormal value, is to use the whole of this current in creating a magnetic flux round the contacts where the circuit is broken.

Systems, such as Thury, Austin and the new Booster method, are based much on the same principle. The armatures are designed to carry the total current in the system without heating. An Arc Welding d.c. machine is subject to periodic short circuits, this being catered for by series directors across the series field and also by neutralising windings laid into the face of the pole pieces and, of course, parallel with the armature conductors. With an alternating current transformer welder, a reactance is used and so the excessive current, due to short circuits, annuls the actual rise of current by opposing the flux which builds up the current, so that such machines can be designed to accomodate short circuits.

When we want torque on the motor shaft we want heat at a minimum in any part of the system. By Joules Law Heat and Work are mutually convertible, so that the more heat the less work and *vice versa*. When the armature or rotor revolves the machine at once starts to generate a counter e.m.f. which follows the supply e.m.f. very closely if the machine is properly designed.

Another form of short circuit may be brought about inductively by using alternating current: thus if one leg of a phase passes through a magnetically closed circuit of ordinary cast iron or steel the temperature of the metal will increase very rapidly due to hysteresis; the metal may eventually become heated up to about 800 degs. Cent. at which temperature magnetism will leave the steel and the temperature remain; this temperature would destroy the cable. This is known as the decalescence period. There have been many instances where this phenomenon has been inadvertently created with very peculiar issues. On one of the first large sets in Glasgow the stator winding cables passed through cast iron pipes and the cable sockets heated and unsweated surreptitiously until the cause was found. If it be necessary to pass one leg of a phase through metal, let it be non-ferrous or non-magnetic metal or, if of magnetic metal do not make it continuous but leave an air gap in it so that the magnetic circuit is not closed.

A voltmeter or a potential transformer is a short circuit but its current is limited by the resistance of the winding in series with the volt meter coil. The transformer sets up a counter e.m.f. not by rotation like the motor, but by reason of the rate of change of magnetic lines. The counter e.m.f. vectorially is 90 degs. in advance of the applied e.m.f. which leads us on to another form of short circuit called resonance. The electro-static capacity can be so great as to preponderate over the inductance and so give a higher e.m.f. at the delivered end than at the delivery end. This opens up a very wide subject which involves the use of electro static condencers. The balance of inductance and capacity is the means towards a unity power factor. This subject is now well understood and is taken into consideration on scheming out alternating current work.

A very useful way to study capacity and inductance is by observing telephone circuits. On walking along a road we find the telephone wires as small as consistent with stability. The reason is to limit its electro-static capacity. On lines with short poles with a single wire earth return it is difficult to get a signal through at all. If you look at four insulators on a pole arm and cast your eye along the line to the next pole you will observe the four wires have turned round one fourth of a circle; this turning of the group of wires probably continues to a making-off pole: the spiral may then be effected in an opposite direction. With a double line or metallic circuit the lines may "talk to each other" if the electro-static capacity is increased by rain or frost enlarging the surface of the wires; the interaction causes cross talk at the telephone instruments. The wireless aerial also introduces the studying of inductance and capacity. The receiving aerial should be in line with the sending aerial which should dip towards the set. The aerial should be out of parallel with other adjacent wires or walls.

At the close of his paper Mr. Laird illustrated and elaborated many of his points by means of diagrams drawn on a blackboard, and comments and queries relative to these were made by Mr. A. B. Muirhead, of the West of Scotland Branch; Mr. R. L. Angus, Mr. James Tweedie, Mr. James Garven, and others.

On the motion of Mr. Garven, chairman of the Ayrshire Branch, a cordial vote of thanks was accorded to Mr. Laird for his interesting paper.

An Address.

A. B. MUIRHEAD (Past President of the Association).

Mr. A. B. Muirhead, a past president of the A.M.E.E., being called upon by the Chairman to address the meeting, said he had been reminded that it was just about ten years since the meeting was held in Ayr at which the Ayrshire Sub-Branch was formed. They still remembered with gratitude the helpful part played by Mr. Angus in enabling them to have a very pleasant meeting and to get a good start off. He would like to say something to those present about the Association of Mining Electrical Engineers with which he had been in close touch since its inception. The Association was more necessary today than ever it had been. The use of electrical plant in mines had grown abnormally and had now reached the stage when it demanded more skilled attention than ever. They all knew the struggle the British mining industry had had to undergo in recent years and they knew too that the introduction of electrical plant underground had been the salvation of the industry. That had caused the influx of a large number of men responsible for the work and maintenance of this plant. The A.M.E.E. existed primarily for the purpose of spreading practical knowledge of the application of electricity to the mining industry.

One of the things that had made Scotland what it is had been the desire of its people in the past to obtain knowledge; one of the things that had made the country great had been the unwavering quest of the knowledge that would overcome difficulties. In handling electrical plant underground many difficulties had to be overcome, and there was especially the difficulty of personal ignorance; it was impossible to understand why anyone should allow himself to get into that state of mind in which he had no wish to improve his standard of life and work.

The men in charge of and working electrical plant underground ought to have such knowledge of it as would enable them to understand its behaviour, and the A.M.E.E. was out to help such people. The fact that its membership was so broad that it included those underground and those on the surface, the manufacturing engineer and the designer of electrical plant, meant that there was a vast amount of knowledge within the Association. The Journal, *The Mining Electrical Engineer*, alone was well worth the annual subscription, which for a full member was only one guinea a year, for an Associate Member 17s. 6d., and for a Student Member 12s. 6d.

Another thing he would like to emphasise was this: there was no reason why the men responsible for the handling of the coalcutting machines should not be members of the Association. The Association was open to them, and by becoming members they would get the literature of the Association and be able to keep themselves abreast of the discussions and developments going on within the industry in which they were engaged. He knew well the difficulties of working a Branch in a rural district such as Ayrshire where the men were so widely scattered. He knew the difficulties of getting representative meetings and of keeping up enthusiasm, but it was a good and healthy thing if even only a few of the men in each area gathered together to discuss the things of their business and experience and to learn from the knowledge and experience of others.

In spite of the many troubles that had afflicted the coal trade in the past two years the membership of the Association had kept remarkably steady. It was round about 2000. Through some special propaganda work carried out in the Fife area there had been a large accession of membership there and they had the feeling that today Scotland was doing its bit in maintaining interest in this Association, which was admittedly doing valuable work for those interested in electrical engineering in mines.

Mr. Muirhead expressed his pleasure at seeing so many present at that meeting. It shewed they were interested in these things and if it meant a few new members the committee of the Ayrshire Branch would be well pleased and the executive of the Association would be highly delighted. He would like to take that opportunity of personally expressing his thanks to Mr. Angus for presiding at that meeting. He was very grateful for the sympathetic interest Mr. Angus had taken in the work of the Association in years gone by and for coming there to take the chair that night. He asked them to accord to Mr. Angus a very hearty vote of thanks.

Mr. ANGUS acknowledged the compliment and said he would like to express the appreciation of the members of the Ayrshire Branch of the work done by their secretary, Mr. J. C. MacCallum, during the past ten years. He had earned the gratitude of all the members.

At the close of the meeting the members were entertained to tea by Mr. Angus.

NORTH OF ENGLAND BRANCH.

Pre-Frequency Change: Notes on the Selection of Electrically-Driven Plant.

S. BURNS.

(*Meeting held 6th December*, 1930).

Compliance with the frequency standardisation requirements of the North East England Electricity Scheme involves extensive operations on Consumers' premises with attendant engineering difficulties about which much has been said and written already; it also imposes obligations about which less has been heard. The major obligation, judged by reference to the expenditure involved, requires the Power Company, as Authorised Undertaker acting upon behalf of the Central Electricity Board in this matter, to carry into effect a 40/50 cycles change-over of Consumers' electrical and incidental mechanical plant in a manner that is commensurate with sound engineering practice and with the Consumers' reasonable demands; the other is a moral obligation upon the consumer to take such steps as are expedient to minimise change-over expenditure upon new plant ordered and set to work between now and the date when a 50 cycles service can be afforded to the premises concerned. The importance of this latter obligation will be recognised if it is borne in mind that after allowance has been made for a systematic reduction of the area in which 40 cycles services are available the probability is that in the course of the next seven years some 3000 three-phase motors will be newly connected at 40 cycles temporarily and that in about 75% of these cases some alteration of motor speed may be permissible under ultimate 50 cycles conditions of working.

It is not proposed in these notes to touch upon the many and interesting problems relating to the 40/50 cycles change-over of existing plant, but to treat only of the rather different problems which are presented in connection with new equipment; the notes, therefore, may be taken as a plea to the user of electrical and incidental apparatus to take advantage of technical investigations which already have been completed and of others now being made. Such notes necessarily must be sketchy and discursive.

As indicating differences in the treatment of old and new plant change-over it may be explained that whereas the performance of new straight 50 cycles plant must be comparable with that of the straight 40 cycles plant it replaces, the 50 cycles performance of new apparatus, if of special design suited to interfrequency working, must be compared with that of the straight 50 cycles equipment which in other circumstances the Central Electricity Board would ultimately have to provide.

The practicability of installing motors of special design where this can be done without detriment to the user has been carefully considered; such motors, of course, would not be employed unless their extra cost, coupled with that of drives alterations at a later date, together amounted to a sum less than the estimated cost of replacement of the straight 40 cycles equipment by new 50 cycles equipment designed for operation at the nearest practicable speed.

Preliminary conversations with Manufacturers clearly indicated the absence of general agreement on this subject; usually the terms "interfrequency" and "dual-frequency" were confused: some Makers had endeavoured to improve the 50 cycles performance of their "straight" 40 cycles motors with a view to "interfrequency" working, and others *vice versa*; whilst others again, had in mind a motor designed to give equal performance at either frequency without reference to the respective performance of either "straight" machine. Accordingly, the term "Interfrequency Motor" was defined by the Power Company as follows:—

"*By* 40/50 *cycles Interfrequency Motor* is meant a three-"phase Induction motor so designed that without altera-"tion of electrical connections or impressed voltage it "will develop the same brake-horse-power at either fre-"quency, though with an approximately 25 per cent. "increase of speed at the higher periodicity; the motor "to conform to B.E.S.A. Standards in respect of over-"load capacity and temperature rise under both con-"ditions of working: F.L./½L. efficiencies and power "factors at 50 cycles should equal those of the "straight" "50 cycles motor of similar electrical rating but at 40 "cycles may be respectively 2 per cent. and 8 per cent. "lower than for the corresponding "straight" 40 cycles "machine."

When considering the behaviour of interfrequency motors in the circumstances in which they will be used in this area it is important not to lose sight of the fact that 40 cycles is a temporary, and 50 cycles the permanent, condition of working; a satisfactory motor can be designed without difficulty.

It should be observed that by "40/50 cycles interfrequency design" is not meant a design which, if expressed in terms of cycles-per-second could be called "45 cycles"; the design should be such that, for a given frame, the motor when ultimately called upon to operate from a 50 cycles supply will be defluxed to the maximum extent that the required standard 50 cycles performance will allow and that whilst operating initially at 40 cycles the machine will be overfluxed to an extent which will permit of a performance somewhat lower than 40 cycles standard but within the limits specified above. The respective degrees of defluxing and overfluxing for a given motor naturally will be determined by the "easiness" or "tightness" of the required electrical rating on the motor frame concerned.

The cooling factor of motors of modern type, fitted with fans, naturally is affected by the motor speed and for 50/40 cycles proportionate speed and voltage adjustment generally is reflected in a reduction of the horse power rating to 78 per cent. (as opposed to the theoretical 80 per cent.) of the 50 cycles equivalent. Nevertheless some Manufacturers adopt the theoretical 100/80 ratio, though others adopt a ratio of 100/75.

These alternative 50/40 cycles output ratios directly affect the size and manufacturing costs of the interfrequency motor, since where 100/80 is the rule there obviously is greater likelihood of the necessity for adopting a larger-than-straight 40 cycles frame as a means of avoiding excessive overfluxing, unduly low power factor, and dangerous overheating, whilst the machine is operating temporarily at 40 cycles.

It is suggested there is a wide application for this type of motor, particularly if care be exercised in the choice of motor speed; and when it is borne in mind that a power user, whose intention it had been to instal a straight 40 cycles 6-pole motor, can be offered instead either a 6-pole or an 8-pole "interfrequency" machine.

It is recognised that the interfrequency motor is not well suited to hoist and hauler gear-transmitted drives of the larger sizes, where, owing to increase of the equivalent Wr^2/g of the rotor after new gears suited to 50 cycles operation had been fitted, additional energy consumption would be entailed: consequently it is not proposed to advocate the use of the interfrequency motor on intermittent gear transmitted drives above the arbitrary limits of 60 b.h.p. if the gear is double-reduction, and 120 b.h.p. if single-reduction.

TYPICAL APPLICATION OF INTERFREQUENCY MOTOR.

Let us suppose that a power user desires to instal a 25 b.h.p. 3-phase 40 cycles 6-pole (760 r.p.m.) motor and that the drive arrangement is such as to render impracticable any other than an inconsiderable alteration of motor speed at a later date; in such event the position is clear: subject to what is to be said later with regard to certain special cases the straight 40 cycles 6-pole (760 r.p.m.) motor will be installed by the Consumer, and the Power Company in due course will replace it by a 25 h.p. 8-pole (720 r.p.m.) straight 50 cycles machine. Necessary mechanical adjustments to the drive also will be undertaken by the Power Company at the time of change-over.

In many instances, however, a 25 per cent. alteration of motor speed will not present difficulty; the simpler case is that where an ultimate speed 25 per cent. higher than 760 r.p.m. is acceptable and where a 6-pole (760/960 r.p.m.) 40/50 cycles interfrequency motor can therefore be fitted. The proposition is sound from the technical standpoint since the performance of this special machine, when ultimately operated from a 50 cycles supply, actually is better than that of the 50 cycles 8-pole (720 r.p.m.) straight motor the Board otherwise would have furnished (see Fig. 1). Admittedly there is a certain disadvantage in that the machine's mechanical dimensions differ from those of additional straight 50 cycles 6-pole (960 r.p.m.) motors the Consumer may purchase subsequent to completion of the change-over on his premises, but this and a possible inconsiderable loss of efficiency during the interim period of 40 cycles service in effect are compensated by a monetary contribution; the Consumer's quota of the purchase price of the special motor is that corresponding to its ultimate 50 cycles electrical rating (in this case 25 b.h.p. 3-phase 50 cycles 6-pole 960 r.p.m.), whilst the Central Electricity Board contributes the difference between this sum and the total cost of the interfrequency machine.

Where a 25 per cent. speed change on the motor only is allowable, providing the ultimate speed does not exceed 760 r.p.m., the interfrequency motor should be fitted with an additional pair of poles; thus, instead of the originally intended straight 40 cycles 6-pole (760 r.p.m.) machine a 40/50 cycles 8-pole (585/720 r.p.m.) interfrequency machine will be fitted and here again the ultimate 50 cyles performance is better than for the straight 50 cycles 8-pole (720 r.p.m.) motor the Board

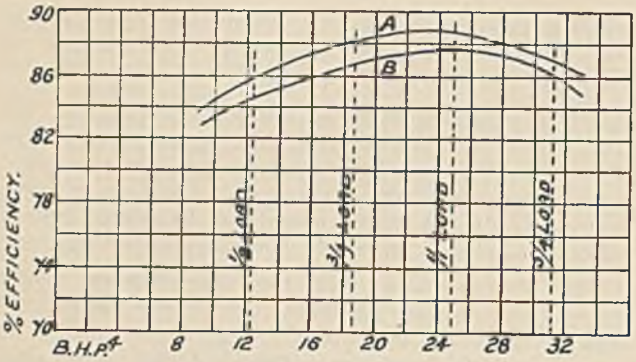


Fig. 1.—*Comparison of Efficiency at Various Loads of:—*

A. 25 *h.p.*, 6-*pole*, 40/50 *cycles Interfrequency S.R. Motor, on* 440 *v.*, 3-*ph.*, 50 *cycles.*

B. 25 *h.p.*, 8-*pole, Straight* 50 *cycles S.R. Motor on* 440 *v.*, 3-*ph.*, 50 *cycles.*

otherwise would have provided (see Fig. 2). The Consumer's quota of the cost of this special motor will be that corresponding to the purchase price of the straight 40 cycles 6-pole (760 r.p.m.) machine he would have installed but for the adoption of the Frequency Standardisation Scheme: and, as compensation for the possible "disadvantages" already mentioned, he receives a heavier and more expensive piece of electrical apparatus than that for which he has paid.

Costs of mechanical alterations to drive may be left out of account since these are contributed by the Board in any event.

For those power applications where a change of motor speed is undesirable or in connection with which the requisite mechanical alterations to drives would be unduly costly, it had been felt that use might be made of special motors so designed that their rated brake-horse-power would be available at the same, or approximately the same, asynchronous speed both at 40 cycles and at 50 cycles; this class would comprise:—

(a) Squirrel cage motors having double wound stators.

(b) Slipring motors having double-wound stators and single-wound rotors; the initially fitted rotor ultimately to be replaced by a new and mechanically duplicate rotor.

(c) Slipring motors having double-wound stators and rotors, the latter with six sliprings fitted.

and the term "dual-frequency" is intended to embrace these several types.

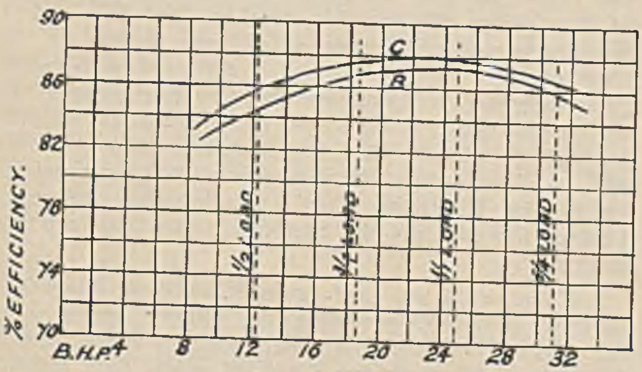


Fig. 2.—*Comparison of Efficiency at Various Loads of:—*

C. 25 *h.p.*, 8-*pole*, 40/50 *cycles Interfrequency S.R. Motor, on* 440 *v.*, 3-*ph.*, 50 *cycles.*

B. 25 *h.p.*, 8-*pole, Straight* 50 *cycles S.R. Motor on* 440 *v.*, 3-*ph.*, 50 *cycles.*

It is recognised that circumstances might necessitate the adoption of machines of this class in rare cases, but their use is not generally favoured for the reasons that:—

1. Their F.L./½L. efficiencies, though approximately the same at 40 cycles and 50 cycles, would be respectively lower than those of straight 40 cycles and 50 cycles motors, whilst F.L./½L. power factors would be somewhat lower on 40 cycles and appreciably lower on 50 cycles than for the corresponding straight machines.

2. The cost of the double-wound motor is high, particularly if of the slipring type.

A modification of this dual-frequency design, however, is well suited to the requirements of those special cases where replacement of the motor would be very inconvenient or where appreciable change of motor speed is impracticable; this motor will have its windings so disposed at the outset that their reconnection, as for a different number of poles, can be undertaken at site in a manner that is electrically sound and within the limited time that is available. To this type of motor the term "dual-frequency (reconnect)" has been applied and defined as follows:—

"*By* 40/50 *cycles dual-frequency* (*reconnect*) *motor* is "meant a three-phase induction motor designed to conform to B.E.S.A. standards and so arranged that a "convenient method of reconnection of its stator and/or "rotor windings at site will enable it to develop the "same brake-horse-power at the same or approximately "the same asynchronous speed at 40 cycles and at 50 "cycles. F.L./½L. efficiencies and power factors are to "be approximately alike at both frequencies and at "50 cycles are not to be lower than the F.L./½L. efficiencies and power factors of a straight 50 cycles motor "of equivalent electrical rating."

In general it may be taken that the application of the dual-frequency (reconnect) motor of squirrel cage type will be infrequent but that its use is strongly advocated where large slipring motors are concerned, notably in the case of direct a.c. geared winding engines.

APPLICATION OF DUAL-FREQUENCY (RECONNECT) MOTOR.

As an illustration of the application of the dual-frequency (reconnect) slipring motor to winder service mention might be made of one of several electrically-operated winding engines proposed shortly to be set to work in this area. Here the specified duty is to raise 100 tons of coal per hour from a depth of 827 feet with a 20 seconds' decking interval per trip, for which purpose a motor of root-mean-square electrical rating of 380 b.h.p. is necessary.

The dual-frequency (reconnect) motor that is to be fitted will be of the 12/14-pole type; consequently the winder will operate during the interim period of 40 cycles supply at a speed approximately 5 per cent. lower than the ultimate and specified speed, raising coal at the rate of 96.5 tons instead of 100 tons per hour, and developing a root-mean-square electrical rating of 345 b.h.p. for the time being (see Fig. 3). The Consumer's quota toward the purchase price of the motor of this winding engine therefore will be the sum corresponding to the purchase price of a 345 b.h.p. straight 40 cycles 12-pole machine with the Board contributing the balance required for the 380 b.h.p. 40/50 cycles 12/14-pole dual-frequency (reconnect) motor that is to be used.

Gears alterations will not be necessary but the labour and incidental charges for dismantling, reconnecting, and re-assembly, of the motor at site will be chargeable to Change of Frequency Account.

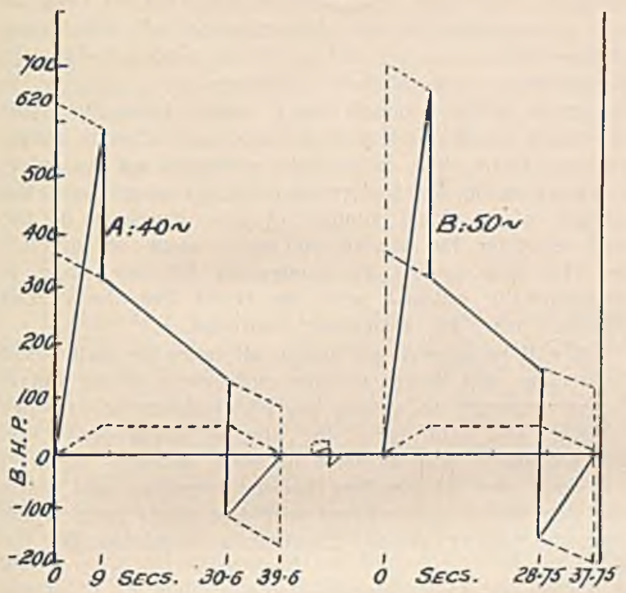


Fig. 3.—*Comparison of Winder on* 40 *cycles and* 50 *cycles.*

A. *Initial* 40 *cycles*: 96.5 *Tons/Hour*: 345 *R.M.S. B.H.P.*

B. *Ultimate* 50 *cycles* : 100 *Tons/Hour* : 380 *R.M.S., B.H.P.*

CENTRIFUGAL PUMPS.

Investigation of the design of interfrequency motors led naturally to the consideration of interfrequency centrifugal pumps; in this case the object is to minimise change-over expenditure not only upon the pumping plant itself but also upon the surface and underground houses in which such plant is accommodated. It should be explained, in this connection, that the problem of pumping-plant change-over has been approached with due regard to the responsibilities involved and with the knowledge that one of the last items of equipment with which a liberty could be taken is the pumping machinery.

As with motors, so with centrifugal pumps; a stipulation must be that under ultimate 50 cycles running conditions the overall efficiency of the pumping system at least shall equal that of the straight 40 cycles plant which otherwise might have been fitted and that preferably it shall not be lower than the efficiency of 50 cycles equipment of straight design. This is not to say that the initial 40 cycles and ultimate 50 cycles pumping duties necessarily must be the same, though this, of course, is desirable; the suggestion here made is that the Consumer's concern is with power cost and that some variation of the pumping duty, expressed in gallons per minute delivered against the same or an only slightly altered total head, will not be considered objectionable so long as the total power cost in respect of the pumping of a given quantity of water is not increased.

At the time of 40/50 cycles change-over, and consequent increase of shaft-speed, centrifugal pumps of different mechanical arrangement would be modified by different methods, but a point to bear in mind is that the designer's calculations will take account of a 50 cycles pump required to operate temporarily at 20 per cent. lower-than-normal speed rather than of a 40 cycles pump required for ultimate service with a 25 per cent. speed increase.

The following examples will serve to illustrate the methods likely to be employed:—

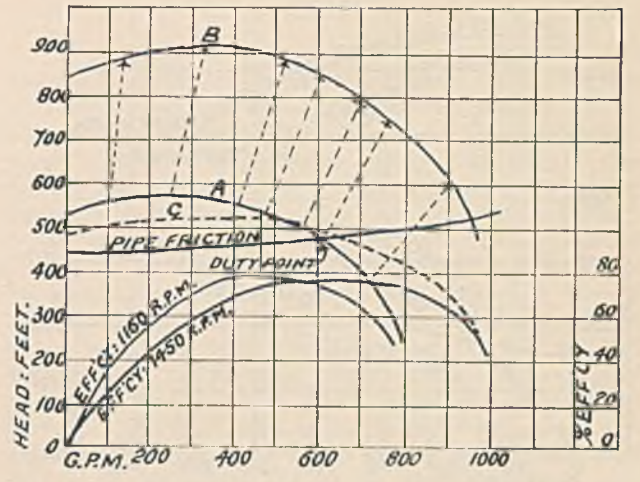


Fig. 4.—*Effect on Centrifugal Pump of change from* 40 *cycles to* 50 *cycles.*

A. *Head-Volume,* 40 *cycles,* 7-*stage,* 1160 *r.p.m.*

B. *Head-Volume,* 50 *cycles,* 7-*stage,* 1450 *r.p.m.*

C. *Similar to B, but with* 3 *stages removed and dummy stages inserted.*

(a) Assume a 7-stage 1160 r.p.m. pump designed to raise 600 g.p.m. against a total head of 480 feet including a frictional component of 3 feet; this pump at 1450 r.p.m. would be capable of delivering 600 g.p.m. against 850 feet total head, equivalent to 121 feet lift per stage, and the case is a straightforward one since reversion to 480 feet head involves nothing more than the simple removal of three stages. With a sectional type pump the corresponding three cells could be removed as well and overall efficiency would be maintained but if of the casing type dummy parts would need to be fitted, with a consequent fall of efficiency in the order of 1½ per cent. due to a slight frictional resistance to the water passage through these dummy stages (see Fig 4).

(b) Frequently, however, the relationship of head and volume will be such that the removal of an exactly appropriate number of live impellers is impracticable. Take, for example, a 6 stage 1160 r.p.m. pump designed to raise 460 g.p.m. against a total head of 500 feet. If ultimately, two stages were removed and the pump speed increased to 1450 r.p.m. the available output would be 540 g.p.m. against approximately 520 feet head, again with practically no loss of pump efficiency (see Fig. 5). In this case, however, the horse-power of the driving motor would need to be increased by about 25 per cent. and Consumer's quota of the cost of the 125 b.h.p. 4-pole 40/50 cycles interfrequency motor would be a sum corresponding to the purchase price of a 100 b.h.p. 4 pole straight machine (see Fig. 6).

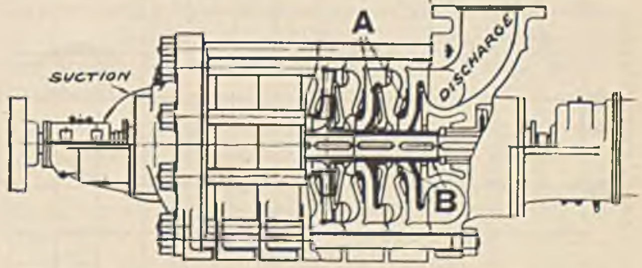


Fig. 5.—*Arrangement of Turbine Pump, impellers of two stages removed.*

A. *Loose Guides as fitted for* 50 *cycles drive.*

B. *Distance Pieces.*

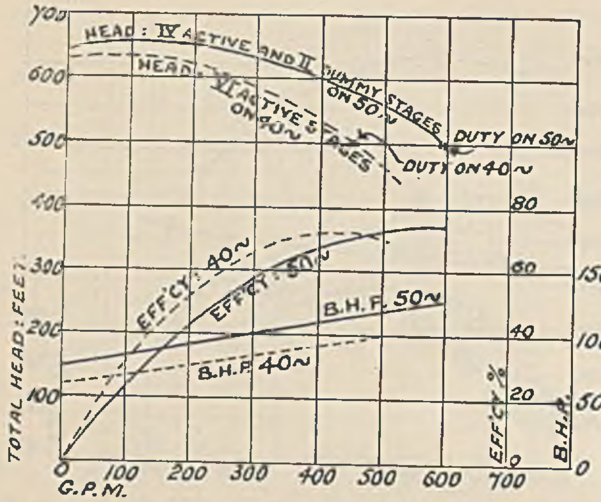


Fig. 6.—Performance of Turbine Pump on 40 *cycles and* 50 *cycles: Speeds* 1170 *r.p.m. and* 1460 *r.p.m.*

It should not be overlooked that when ultimately the rate of flow of water in the rising main is greater than that for which the pipe-line originally was designed, the pipe-line frictional losses will be correspondingly increased; this loss will be inconsequential so long as care is exercised in the determination of initial and ultimate pumping duties and where the pipes are liberally dimensioned, as is usual at Collieries.

(c) A further though more costly alternative and one which is attractive in that initial and ultimate duties are maintained alike, is to make provision on the inter-frequency pump for the removal of all stages and the refitting of an equal number of new impellers of the same diameter but having an easier angle of impeller tip. By this means, the equivalent lift per stage is proportionally reduced, with the result that the overall efficiency may be somewhat improved.

It will be appreciated that in all cases the Authorised Undertaker will desire to take such steps at the outset as are necessary to ensure the practicability of impeller removals and refitting at the time of changeover; on this account it will be wise in some instances to meet the extra cost of zinc-free bronze impellers and stainless steel shafts as compared with less costly parts which otherwise might satisfy Consumer's requirements.

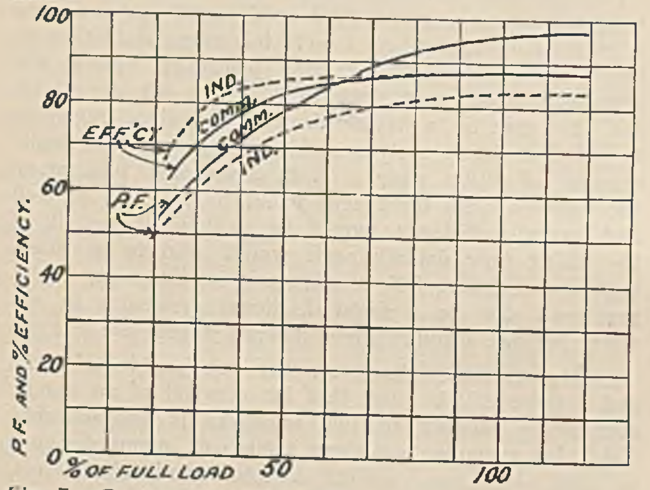


Fig. 7.—Comparative Characteristics of 25 *h.p., a.c. Commutator Motor,* 40/50 *cycles,* 720 *r.p.m.; and S.R. Induction Motor,* 25 *h.p.,* 40 *cycles,* 760 *r.p.m.*

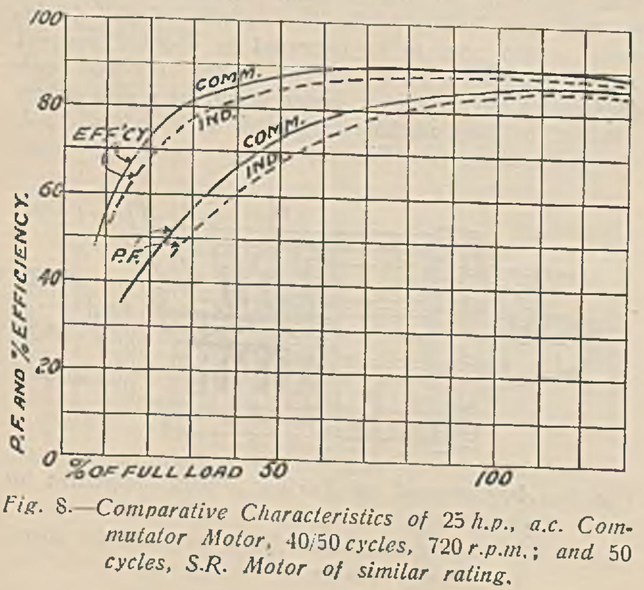


Fig. 8.—Comparative Characteristics of 25 *h.p., a.c. Commutator Motor,* 40/50 *cycles,* 720 *r.p.m.; and* 50 *cycles, S.R. Motor of similar rating.*

THE A.C. COMMUTATOR MOTOR.

Cases may arise where direct-coupled motor driven apparatus cannot be altered in speed or where its replacement would be inexpedient on the score either of inconvenience or excessive cost; in such event the application of the a.c. commutator motor should be considered. For example a three-phase motor of this type can be arranged to run at the same speed at 40 cycles and at 50 cycles, by re-adjustment of the regulating winding brush position and, as a case in point, the relative 40 cycles and 50 cycles performances of a 440 volt, 720 r.p.m. machine actually are better than those of the 6 pole (760 r.p.m.) and 8 pole (720 r.p.m.) straight slipring motors (see Figs. 7 and 8). The a.c. commutator motor is necessarily much more costly than the straight machine and admittedly there are many colliery applications for which it could be considered unsuitable; nevertheless its utility for inter-frequency working should not be overlooked.

These notes are incomplete and some time must elapse before definite pronouncement can be made upon the generally similar problems which arise in connection with other types of plant, notably that required for installation at or near the coal face; they are now tendered as an indication of the Power Company's desire to take full advantage of any advice Consumers' Engineers may care to proffer in regard to the installations for which they are responsible and of the Company's anxiety to work in close collaboration with such engineers.

WARWICKSHIRE & SOUTH STAFFS. BRANCH.

A good attendance of members was recorded when the Branch met in Cannock on November 13th last. The following were elected to membership—John Ellison (Member), W. N. Monckton, E. Fokinther, and H. Hedges (Associates).

The Secretary informed the Meeting that as the result of the private donations of members a sum of £4 6s. had been remitted to the Brownhills Council in connection with the Grove Pit Disaster.

Mr. Harvey, in a letter, expressed his thanks for the kindly expressions of the goodwill of the Branch upon his retirement from office.

Mr. Henry Joseph in a paper entitled "Trouble" dealt with possible causes of breakdown in both electrical and mechanical gear and described a novel method of preventing boiler scale. The lecture was profusely illustrated with lantern slides and a lengthy discussion ensued. Mr. Dixon, in the Chair, and Mr. Maynard expressed the Branch's thanks for the very interesting paper which Mr. Joseph had presented so lucidly.

Trouble.

HENRY JOSEPH.

If this were a sermon the author might adopt as his text—"The trouble is a pleasure." When a large and important motor breaks down, just as the electrician begins to get busy trying to get over the difficulty, a message reaches him of the failure of a cable in another part of the pit. Then, while engaged in the impossible task of being in two places at once, a cheery messenger brings the welcome news that one of the main generators has sat down. Under those circumstances the engineer does not express in his best and most dignified language his thorough appreciation of the experience. But, after a lapse of time he comes to admit that there is something very fascinating in pitting one's wits against adversity and successfully solving problems which every engineer must accept as part of his day's work.

After all, it is only thus that an engineer's experience is built up, and the object of this paper is to indicate a few of the problems the author has had to cope with and how he tackled them. As a result he formed certain theories and it is hoped that these notes will lead others to tell us of their experiences, to criticise the author's methods, and, if necessary, correct his deductions.

Many of the early troubles were the result of lack of experience, either on the author's part or of general engineering knowledge at the period and so they are no longer of practical interest. Yet one hears occasionally of some of them being repeated even to-day, so perhaps one may be excused for referring to them.

One day, as an apprentice in an electrical manufacturers' works, the author was on the test bed while three large rotary transformers were running with a wooden fencing separating them from the gangway which ran the length of the erecting shop. These machines were for converting 440 volts to 2750 volts d.c. and consisted of doublewound armatures with a L.T. commutator at one end and a H.T. commutator at the other rotating in a common bi-polar field. When standing on the side of the machines remote from the gangway, the author noticed a large armature fitted with an iron pulley suspended from the overhead travelling crane coming down the shop. Suddenly the armature swung round and was drawn against the pole-piece of the transformer and it was obvious that if it travelled much further it would foul the H.T. commutator. Shouting to someone to switch off the transformer and with more zeal than discretion the author rushed round the end of the fence, grabbed at the pulley of the suspended armature and wrenched it away from the running machine. The author still hears the men shouting and sees their white faces as they expected him to fall a charred corpse on the floor, for at the moment he touched the pulley it was actually in contact with the H.T. commutator. But Providence is kind to babes and sucklings for at that instant it was also touching the pole-piece and earthing the commutator to the test bed. The moral of this experience would appear to be—"Think first and act afterwards."

MAINS.

In the early days of electricity supply, about the year 1900, the author was assistant engineer at the Harrow electricity works. In those days Harrow boasted of one of the most iniquitous mains systems. The distributors consisted of bare hard drawn copper strip laid in concrete ducts and supported on porcelain insulators. The service branches were triple or twin lead covered cables drawn through earthenware pipes into the consumers' premises. As Harrow is on a hill the distributors in the upper part of the town did not give much trouble but in the valley in wet weather the ducts got full of water with disastrous results. However this did not happen often, the principal trouble being water creeping along the service cables which burnt out at frequent intervals. To make matters worse the whole town was linked up solid so when a service shorted we just piled up coal in the boilers and let the fault burn itself out: later, when most of the reasonable people had gone to bed, we isolated a section and pulled in a new service.

When the author was at Folkestone, Melton-Mowbray, Dorking, and elsewhere he spent many sleepless nights locating faults on bitumen cable systems and replacing sections of it with 3-core armoured cable laid direct in the ground. In those cases the inherent faults of vulcanised bitumen cables were exaggerated by reason of the fact that the cables were laid in creosoted wooden troughs on porcelain bridges and filled in with bitumen. There appear to be certain soils which have the property of setting up unpleasant relations between creosoted wood and bitumen, and consequently in certain areas we would find both the wood and the bitumen reduced to a slimy pulp.

Faults on these cables were of such frequent occurrence that we had to keep a breakdown gang with a special emergency kit ready to send out at a moment's notice. At the works and at the author's house there was a bank of carbon lamps connected between the neutral and earth, the one at the works being in parallel with a low resistance in series with a fuse. When these lamps lit up it was time to start out and locate the fault. There was a plan of the mains shewing certain feeder pillars etc., at which the town could be divided up into sections. This was photographed and a copy given to each of the outside men to carry with him always.

The correction of these troubles followed a definite routine. Men went out on bicycles to the various disconnecting points so that sections of the mains were isolated on to separate feeders. It was a simple matter then by flashing each feeder in succession to see which section the fault was on. Than the search party went out with a large wooden triangle on wheels wound with a large number of turns of fine wire across the ends of which was a telephone receiver. The rest of the emergency kit was kept in a large wooden box, with a place for each article, which was carried round on a hand-cart.

The next step of course was to split up the faulty section till we got down to one length between two boxes. This was disconnected and fed through a motor-driven contact breaker and a bank of lamps. We then wheeled the triangle along the cable and listened to the clicks on the telephone till we got to the fault.

With armoured cable this method is not reliable. In such cases the author generally used a modified form of Murray's loop test and got, as a rule, very accurate results (Fig 1). A bridge consisting of a slide wire on a

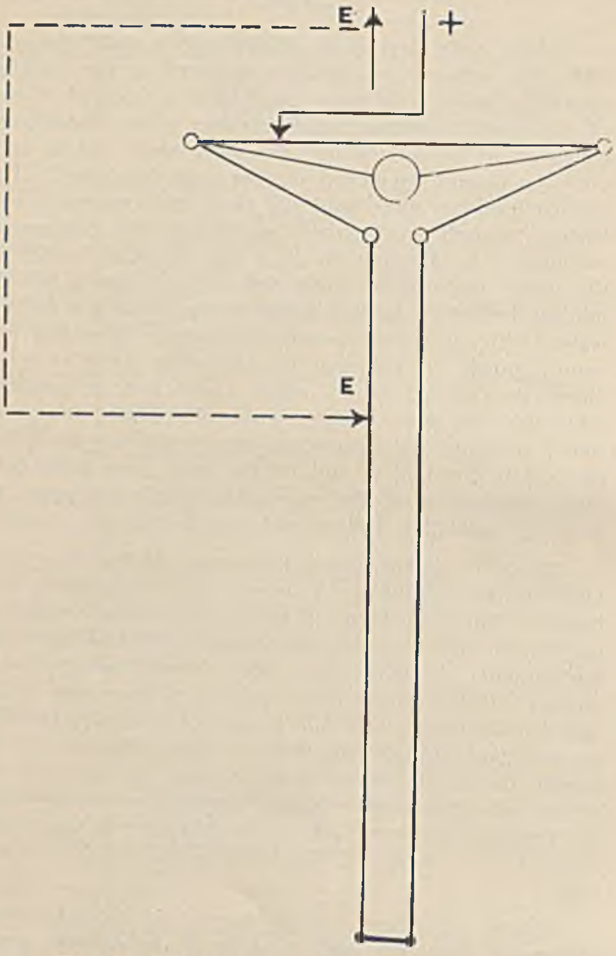


Fig. 1.—Adaptation of Murray's Loop Test.

wooden base one metre long divided up into centimetres and millimetres was used. A milli-voltmeter was connected across the slide wire which was connected by means of stout leads to two cables, one of them the earthed one and the other a sound one; or, failing the latter a V.I.R. cable was run along the ground. The far ends of the two cables were connected together forming with the slide wire a Wheatstone's Bridge circuit. The live current was taken through a lamp to the slide wire and the return was through the fault, which was found at a distance away corresponding to the percentage of the slide wire at which a balance was shewn on the milli-voltmeter, after correcting for the difference in section of the leads and the sound cable if necessary. In one case an earth on a length of .1 sq. inch H.T. cable 4½ miles long connecting Hythe to Folkestone was located so accurately by this method that the fault was found within the limits of the size of the hole when it was opened out. And thereby hangs a tale.

A new supply at Hythe had been started for some months, the power being transmitted at 2750 volts d.c. by means of those very rotary transformers which, as already mentioned, were so nearly the cause of a fatality. In August the sea front and the banks of the canal and the cricket field were to be illuminated by means of coloured lamps. All the wiring was finished and ready to switch on when a messenger arrived post haste on a bicycle from the sub-station to say that they could not get any juice through from Folkestone. However, there was a duplicate cable and that enabled the illuminations to be ready: the next morning the fault was located by Murray's loop test as already described. About 11 o'clock in the morning the author was on the switchboard gallery at Folkestone and the Chief came along to ask how matters were going. "Oh, quite all right" I said. "The fault is in the works' yard and they are just digging it up." "And how about the other cable?" he asked. "Oh, that is all right, we ran through the evening on it." "Yes," said he, "That was last night, but is it all right now?" Like a wise man he suggested that the other cable should be tested at once. To cut the long story short it was in fact found that both cables were broken down to earth—under the ash tip! The cable was a two-core paper insulated, load sheathed, wire armoured cable laid solid in bitumen in an iron trough, the paper being of course impregnated with resin oil. Presumably the switching-off of the spare cable had acted as the last straw to the proverbial camel. Moral: "Never take anything for granted."

That was the only trouble experienced with that cable but there were many troubles with the H.T. generators and the rotary transformers. A heavy short on the L.T. mains would lead to a surge on the H.T. which would create very high voltage rises at the ends. That trouble was overcome by cutting the H.T. feeder into four sections of unequal lengths by means of link disconnecting boxes, thus greatly reducing the surge effect on the ends.

As engineers used to handling cables the members would be familiar with the phenomenon of water creeping along a cable from a fault which had been lying in water. It was common experience in cases of that kind for many yards of the cable to have to be cut away to waste before dry cable was reached. The author had known cases where the bare conductors of a cable having been lying in a pool of water overnight in a rain-storm it had been necessary to relay 100 yards either side of the fault after cutting at intervals of a few yards before one got clear of water. He was very surprised therefore when recently attending a meeting of an electrical engineers' association in Birmingham to hear speaker after speaker referring to tough rubber sheathed cable as being liable to conduct moisture—as if this fault were peculiar to this class of cable or had in fact anything to do with the nature of the insulation. The cause is undoubtedly due to capilliary absorption of the water along the interstices between the strands of the cable, the action being greatly assisted by electric osmosis.

A little while ago the author came across another trouble of a similar origin. Two large circuit breakers ahd been installed in the sub-station of a factory and from them single conductor V.I.R. cables were taken about 8 to 10 feet along the ceiling of the sub-station through an earthenware pipe and thence upwards about 20 ft. to the top of a pole where they were connected to overhead lines. After some months trouble was experienced with the circuit breakers, the oil frothing up and behaving as if it were damp, which as a matter of fact it was. The breakers were seldom tripped but when they were the live contacts reached the lower layers of the oil in the tank which was so thoroughly emulsified with water as to be a very fair conductor and the mixture started boiling over.

At the time it was thought to be due to moisture having got into the breaker or the oil when the gear was installed and elaborate precautions were taken to insure that everything was clean and bone dry and the breakers filled up again with new oil. However, after a further period of some months terminating with very wet weather the trouble occurred again.

Considering the matter very carefully it was decided that water was flowing down the cable and filling up the breakers. The cable was cut and the ends sweated into long sleeves so as to stop effectively any possibility of water percolation. The breakers were cleaned out and filled with new oil and no further trouble has occurred. When the cables were being cut the presence of water was definitely established by the hack saw blade being wet.

GENERATING PLANT.

The author has had some very unfortunate experiences as the result of priming of boilers. On more than one occasion reciprocating engines have been almost wrecked by water coming over into the cylinders. It is in such circumstances that one has brutally thrust home the truths that (1) water is an incompressible fluid, and (2) a rapidly moving piston cannot suddenly be stopped by a mass of water between it and the top of the cylinder without something breaking.

On one of these unfortunate occasions all the big end bolts were either stretched or broken, the main bearing bolts similarly suffered, the crank shaft was bent and a lot more damage done. It happened in the early hours of the morning and the real cause was never ascertained for certain. The author held a strong suspicion that the feed pump had been working overtime while the boiler was on short time, so to speak. After fitting specially designed separators and changing the fireman the trouble was never repeated so it was not possible to pin down the ultimate responsibility.

In those days boilers were laid off in turn periodically for cleaning, which was done with turbine cleaners in the tubes and cold chisels in the drums. Thousands of boilers are still cleaned in that way. It does not appear to be generally known that there is a very simple method on the market by which not only can boilers be got absolutely free from scale while in service but also the further formation of scale prevented. In principle this method consists of passing a very low pressure d.c. current through the boiler continuously. A large piece of steel fitted with a terminal is welded to the front plate of the boiler and a similar one is welded to the back end. A small motor generator supplies about 6 volts through a low resistance circuit which is controlled by means of rheostats. The terminal at the front end is positive and that the back end negative. That is all. The current is kept flowing and the scale automatically drops off as it forms.

At Hawick, up to about 1910, there were only reciprocating sets; as an extension a mixed pressure turbine was installed with extraordinary increase in economy. The set took the exhaust steam of the largest reciprocating set and one of the smaller ones at full load, and gave its full-load output without requiring any live steam. That part of the scheme was quite alright, but there was a snag which later experience got over.

The generator was a d.c. one and the speed was 3000 r.p.m. As every electrical man knows, steam turbines call for high speeds but commutators do not and it was found in this case that any slight disturbance on the mains started sparking on the commutator which developed in a few seconds into a flash-over and out came the breaker. Then all the brushes had to be dismantled, shorts cleared from the commutator bars, the commutator polished, the brushes re-bedded, and in all a series of operations which took the best part of an hour.

In the meantime the steam consumption having risen by about 50% a corresponding increase in reciprocating plant had to be set to work and stand-by boilers had to be forced up and put into commission. Before this could be done the mains voltage had fallen and no-volt trips on consumers' motors had shut down a lot of the load; moreover, factories were clamouring for information and using most offensive language on the telephone. It is regretted that the office boy was instructed to give a stock answer: "The strap has come off the boiler" but intelligent consumers became sceptical and abusive.

Finally, after much experimental work in the direction of compensating coils, diverter resistances, etc., the generator was scrapped for good and all and replaced with a machine having a radial commutator. This, though by no means perfect, was on the whole, fairly reliable. Moral: "Do not try to run direct-current turbo-generators at 3000 r.p.m. but put in gear drives." This of course is always done now, but the makers had to buy their experience.

(To be continued).

STOKE SUB-BRANCH.

Annual Dinner.

The annual dinner and smoking concert in connection with the Stoke Sub-Branch was held at the Metropole Hotel, Church Street, Stoke-on-Trent on Saturday, December 20th, 1930. The Chairman of the branch, Mr. F. Gurney presided over a good attendance of members and friends. The evening was highly successful and all present expressed their appreciation of the enjoyable outcome of the committee of organisation.

The loyal toast was honoured at the call of the Chairman. Thereafter the toast of the Association was proposed by Mr. J. F. Aust, to which the Chairman made suitable reply.

Apologies for absence were communicated from Mr. J. V. Brittain (St. Helens), Mr. G. E. Gittins (Manchester), and Mr. J. H. Aust (Scunthorpe).

The musical programme which followed the dinner and speech-making was contributed by Messrs. Spragg, Forster, Aust and Gumbley, who were singers, and by Mr. Tyson, who entertained the company with the assistance of a gramophone. The evening's entertainment concluded with a cordial interchange of votes of thanks to the artists, the branch secretary and the Chairman.

MIDLAND BRANCH.

Lecture by Dr. H. Cotton.

A Meeting of the Midland Branch was held at the University College, Nottingham, on Saturday, December 13th, Mr. C. D. Wilkinson presiding. After the Minutes of Meeting for November 29th had been read, the Secretary announced that an invitation had been received from the Ilkeston Engineering Society for members of the Branch to attend a lecture to be given at the Ilkeston County Secondary School on Friday, January 23rd, by Mr. L. M. Jockel entitled "The Plant and operation of an Electricity Power Station," illustrated with lantern slides. It was also announced that the visit to Derby Cables Ltd. would take place on January 17th at 3 p.m. The next Meeting of the Branch was fixed to be held at the Nottingham University on Saturday January 31st, at 5-30 p.m., when Dr. Cotton would give the second of the special series of lectures as arranged.

New members of the Branch were elected as follows: Associate: Wm. Hopkins, 116 Nottingham Road, Eastwood, assistant electrician; Member: Chas. Pogson, Station Road, Denby, Derby, engineer.

Dr. H. COTTON, M.B.E., D.Sc., then gave the first of the series of lectures on "Electrical Engineering as applied to Mining Practice," the sub-heading being "The Application of Ohms' Law," of which Dr. Cotton gave several examples on the blackboard.

Mr. C. D. WILKINSON at the close of the lecture moved a vote of thanks to Dr. Cotton.

Mr. W. WYNESS, in seconding the vote, said it was a privilege to have such a tutor and hoped that those present would try to induce friends to attend the next lecture.

The Periodic Advance of the Gate-End Switch.*

Objects.—The objects of the methods illustrated (Diagram No. 1) may be stated shortly thus:—

(i) to limit the length of unarmoured trailing cable to that necessary to follow the movement of the machine, while it is at work;

(ii) To provide, by the use of a length of pliable armoured cable, means to enable the gate-end switch to be moved forward (or backward) daily, if necessary, while avoiding the difficulty of disposing of surplus armoured roadway cable.

(iii) to eliminate temporary jointing of cable *in situ*.

Standardised detachable cable end boxes.—The use of these cable boxes is a feature of the proposal. The intention is that the boxes shall be attached to the cables before they are taken into the mine, so that nothing remains to be done *in situ*, except the mechanical coupling of the several components of the equipment.

The cable-end box may have projecting terminals that are bolted to corresponding terminals in the terminal box of the switch, or in the straight through junction box. Alternatively, these components may be designed as a plug and socket coupling.

In either case the cable box should be bolted to the apparatus to ensure the earthing circuit and to prevent unauthorised or accidental separation.

With such boxes the cable cores may be soldered into their terminals and the cable dielectric may be sealed with molten insulating compound, under favourable conditions.

Advantages.—It is suggested that by this method a substantial saving of electrician's time will be secured, as well as greater reliability and convenience, while the risk of accident will be reduced.

It should be observed that the method is equally applicable to a retreating coal face, by inverting the procedure.

NOTE: Cable end boxes designed upon this principle can now be obtained from several manufacturers.

*From Report of H.M. Electrical Inspector of Mines: 1929.

Danger from Live Electrical Conductors during Examination, Test or Repair. General Regulation 131 *(g)**

CONSIDERATIONS THAT INFLUENCE THE CHOICE OF POSITION FOR APPLYING THE EARTH CONNECTION WITH GENERAL DIAGRAMS TO ILLUSTRATE TYPICAL CIRCUITS AND CLASSES OF SWITCHGEAR.

Typical Circuits:—

(*a*) Single feeder outgoing, [fed from one end only].

(*b*) Duplicate feeders outgoing [fed from both ends from the same source].

(*c*) Inter-connector, [fed from both ends from separate sources].

(*d*) Incoming feeder.

Classes of Switchgear:—

(i) Draw-out type, [pedestal or truck, self-isolating].

(ii) Fixed metal-clad type, [with integral or separate isolator on one side of switch].

(iii) Cubicle type, [with separate isolator on one or both sides of switch].

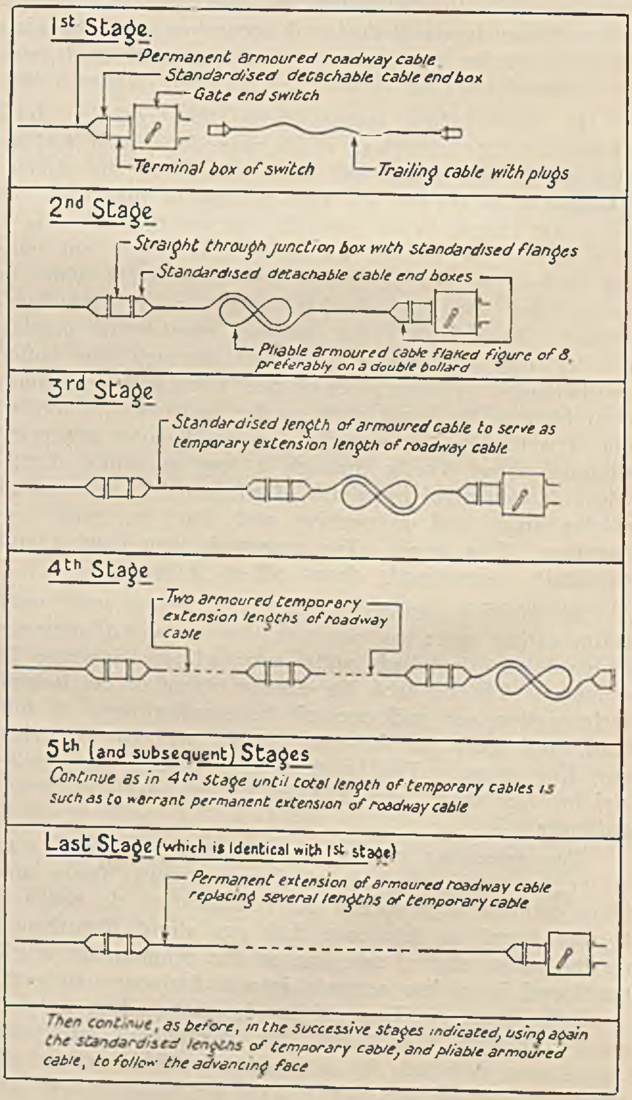


Diagram No. 1.

Comments upon diagrams.—Let us consider each type of circuit with reference to each class of switchgear, premising, in all cases where a circuit breaker is used to close the circuit between line and earth, that the risk that the circuit breaker may be tripped while men are at work upon the earthed line will be provided for by locking the circuit breaker in the "on" position in such a way as to prevent either manual or automatic tripping.

It is also premised that unless the earthing connection can be applied to the terminals of the circuit breaker, it will be necessary to provide an isolator with an earthing position. The isolator should, of course, be interlocked with the circuit breaker through which the circuit will be completed.

TYPE (*a*) CIRCUIT.

[*single feeder fed from one end only*].

1. As such a circuit cannot be live from the distant end it might appear preferable to apply the earth connection at (*y*) rather that at (*x*) [*see* Fig. 1], so that the earth may be directly on the line and in order to interpose the circuit breaker between the earthing connection and the source of supply, but if point (*y*) is selected it will be impossible to use the circuit breaker to put the line to earth and additional mechanism will be required to enable that operation to be performed without danger to the operator.

2. Where Class (i) switchgear is installed [Draw-out, self-isolating type] it is better obviously to select point (*x*) for the earthing connection, *see* Fig. 1 (1) as that permits the use of the circuit-breaker for closing the circuit between line and earth, instead of attempting to apply the earth to the fixed portion of the switchgear after withdrawing the movable portion.

3. Where Class (ii) switchgear is installed [fixed metal-clad type with integral or separate isolator on one side of switch] it is evident that, as means to isolate the circuit breaker from the source of supply are necessary to facilitate periodic examination, the isolator must be connected between the circuit breaker and the bus-bars.

Thus it follows that the earthing connection must be applied at (*x*) [see Fig. 2 (1)] (unless there is a special earthing contact within the circuit breaker), because no terminal at (*y*) will be accessible.

4. If there is a special earthing contact in the circuit breaker, then the earth may be applied at (*y*), with whatever advantage there may be in having the circuit breaker between the earth connection and the adjacent (and only) source of supply.

5. If the design is such that the earth is applied automatically when the circuit breaker is in the "off" position then the earth must be applied at (*y*), but this arrangement can only have a limited field of application, for even upon single feeders there may be plant, such as a synchronous motor, that can feed back into the line.

6. Where Class (iii) switchgear is installed [Cubicle type with separate isolator on one side], it is assumed that two isolators will not be provided for a circuit of Type (*a*) and there must be means, as in the case of Class (ii) switchgear, to isolate the circuit breaker from the adjacent source of supply so that the earth must be applied at (*x*) [*see* Fig. 3 (1)], for the reason given in paragraph 3, except where there is a special earthing contact in the circuit breaker, and in that case the remarks in paragraphs 4 and 5 apply.

7. As to the design of the isolator, the need for an earthing position has been pointed out in the premises, where also the necessity for an interlock with the circuit breaker to prevent the isolator from being used to make or break load current, is indicated.

TYPE (*b*) CIRCUIT

[*duplicate feeder fed from both ends from the same source*].

8. In the case of duplicate feeders the line to be earthed may be live from the distant end, via an adjacent switch, so that there are two sources of supply in effect, although both are presumed to be under the observation of one operator. If line (2) [*see* Fig. 1] is to be earthed it may be live, via line (3) and if line (2) is earthed under that condition the circuit breaker for (3) will be tripped irrespective of whether the earth is applied to (2) at (*x*) or at (*y*).

It is therefore mainly a matter of convenience of application whether the earthing connection is made at one point or the other, but, as in the case of a Type (*a*) circuit, if the circuit breaker is not used to put line (2) to earth, then additional mechanism will be required to enable that operation to be performed without danger to the operator.

9. Where Class (i) switchgear is installed [*see* Fig. 1 (2)], the earth can be applied most conveniently at (x), for the reasons given in paragraph 2.

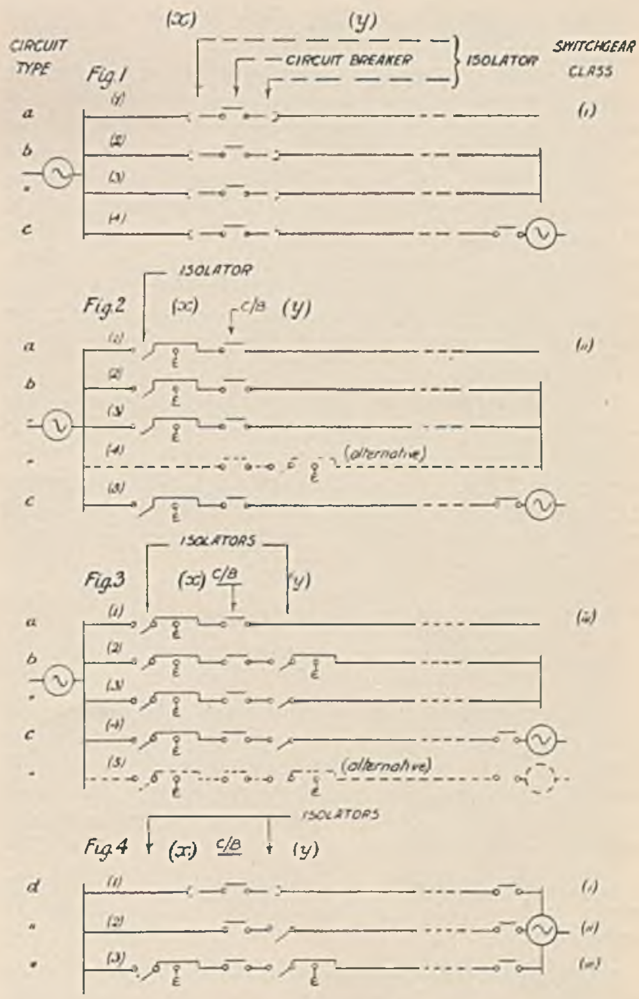


Diagram No. 2.

With this class of switchgear there will be no danger from the direct source of supply (subject to suitable arrangement of details), as the circuit breaker must be withdrawn to apply the earthing connections.

As to danger from the indirect source of supply, via line (3), this is avoided by applying the earth at (x), through the circuit breaker for line (2).

10. Where Class (ii) switchgear is installed [*see* Fig. 2], it is clear for the reason given in paragraph 3, that the isolator must be at (x) as indicated in Fig. 2 (2) and (3) and not at (y) as shewn at (4) in Fig. 2.

Hence, it follows that the only accessible terminal to which the earthing connection can be applied is at (x) unless there is a special earthing contact in the circuit breaker.

That special case has been discussed in paragraph 4 with respect to a circuit of Type (a) for which the earth may be applied at (y).

11. If, however, the earth is applied in a Type (b) circuit, at (y) by means of an earthing contact in the circuit breaker, manually operated, then it is essential that this earthing contact shall be capable of closing on a fault without danger because the line to be earthed may be live from the remote end.

12. It is obvious that, for a Type (b) circuit, an earthing contact which is made automatically when the circuit breaker is "off" is impossible, whether applied at (x) or at (y), because it would prevent the normal use of the duplicate circuit, by tripping the circuit breaker for line (3) whenever that for line (2) opened and vice versa.

13. Where Class (iii) switchgear is installed there is no difficulty in providing isolators on both sides of the circuit breaker, as shewn in Fig. 3 (2) and (3) but if the earth is applied at (y) to a live line by means of the isolator the consequences may be disastrous, unless the isolator is designed to close upon a fault. If, however, the earth is applied at (x) by means of the isolator, and if this isolator is interlocked, as it should be, with the adjacent circuit breaker, then the final closing of the circuit, which puts the line to earth, can be made through the circuit breaker without danger to the operator.

14. It will be necessary that the isolator at (y) shall also be suitably interlocked and where point (x) is selected for earthing but an earthing position is not not required, see Fig. 3 (3). In brief, the isolators at (x) and (y) must both be interlocked with the circuit breaker so as to prevent them from being used either to make or break load current.

TYPE (c) CIRCUIT

[*interconnector fed from both ends from separate sources*]

15. The case of an interconnector only differs from that of a duplicate feeder in that the circuit breakers controlling the two ends of the line are not adjacent and therefore are not under the observation and control of the same operator. The risk, therefore, is greater that an attempt may be made to earth a live line.

16. Where Class (i) switchgear is installed the earth will, as before, be applied at (x) as a matter of convenience.

17. Class (ii) switchgear is not suitable for interconnectors, unless isolators are provided on both sides of the circuit breaker and if they are so provided then the advantage lies in applying the earth at (x) for the reason which has been given in paragraph 13, viz.: that it would generally be disastrous to use the isolator to earth a live line.

18. If there is a special earthing contact in the tank of the circuit breaker, then the earth may be applied at (y) provided, as in the corresponding instance in a Type (b) circuit mentioned in paragraph 11, this earthing contact can be used to close on a short circuit without danger to the operator, reliance being placed upon the tripping of the distant circuit breaker, see Fig. 3 (5) to clear the fault.

19. For Class (iii) switchgear, with isolators on both sides of the circuit breaker, it will be preferable, for the reasons that have already been discussed in paragraph 13 to apply the earth at (x), see Fig. 3 (4).

CONCLUSION.

20. Thus it will be seen that, except for circuits fed from one end only, it is usually necessary and generally preferable to apply the earth at (x).

21. Further, as most switchboards will control duplicate feeders as well as single feeders and as the latter may develop into the former as the installation grows it would appear better, on balance, to make such uniform provision initially as will suffice for either type of circuit in the matter of earthing the line. This desideratum can be achieved by arranging to earth at the point (x), in all cases.

22. The case of an incoming feeder, see Fig. 4, i.e., a line fed normally from the remote end only, has not been discussed previously because it can be regarded as a circuit of type (a) or type (b) if the arrangements for earthing are applied at the normal source of supply to the feeder. Where such a line is controlled at the incoming end by switchgear of Class (i) Fig. 4 (1), there is no reason why it should not be earthed at that end, if desired, and in that case the earth will be applied to the line through the circuit breaker, as before, at (x).

If Class (ii) switchgear with one isolator is installed, the isolator will naturally be introduced between the circuit breaker and the line Fig. 4 (2), so that the circuit breaker may be isolated, on occasion, for detailed examination.

In that case point (x) is not available and to apply the earth at (y) by means of the isolator would be dangerous if the line were live, so that the line must be earthed at the other or outgoing end.

If Class (iii) switchgear with two isolators is installed Fig. 4 (3), then the earth may be applied at (x), if desired, using the circuit breaker to close the circuit between line and earth, but the earth cannot be applied at (y) lest the line should be live at the moment.

NEW BOOK.

H.M. STATIONERY OFFICE.

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

MINES DEPARTMENT.—REPORT OF H.M. ELECTRICAL INSPECTOR OF MINES for the Year 1929. Price 9d. nett.

Manufacturers' Specialities.

The "I.F." Trailing Cable Tester.

This machine has been designed to overcome the difficulties hitherto experienced in locating faults in trailing cables of all types. Whilst there are testing machines which will locate faults from the cores to earth through ordinary rubber covered cables, the greatest difficulty has been experienced in the past in locating such faults in cables encased in an earthing sheath. The object of this machine is to locate faults in earth shielded and other cables as follows:—

Faults between cores: dead shorts between cores: faults from cores to earth in the ordinary rubber covered cable: faults from inner cores to outer earth sheath in fairflex or any other type of sheathing cable: shorts from cores to sheath.

The two illustrations herewith shew respectively a front view of the machine, and a cable in position on the machine for test. As will be seen the machine consists of a small switchboard, embracing three switches for operating the set, and a specially made indicator lamp which serves three function, namely:—

(1) When the lamp does not light at all: indicating dead short.

(2) When the lamp glows in the filament only: indicating a sound cable.

(3) When the whole of the gas in the lamp is illuminated: indicating a fault either between cores, or from the cores to outer sheathing or earth.

Two electrical circuits are provided, the one on the left-hand side of the board being high tension, and the one on the right-hand side of the board being low tension, approximately 120 volts. The first switch operates the high tension circuit, the second switch is merely to test the batteries before operating, and the third switch operates the low tension. An indicator is also fitted to the board in the form of a milli-ammeter.

The method of testing the cables is very simple and effective. To test for a fault to earth: the cores are connected on the high tension side to one terminal, the other terminal being connected to the outer sheathing. This circuit is then brough into operation by switch No. 1, and a high pressure current passes into the cable through the fault and into the outer sheathing This pressure is maintained until the fault becomes carbonised, which is immediately shewn by the indicator lamp becoming extinguished. All that is necessary then is to connect the leads to the low tension side of the

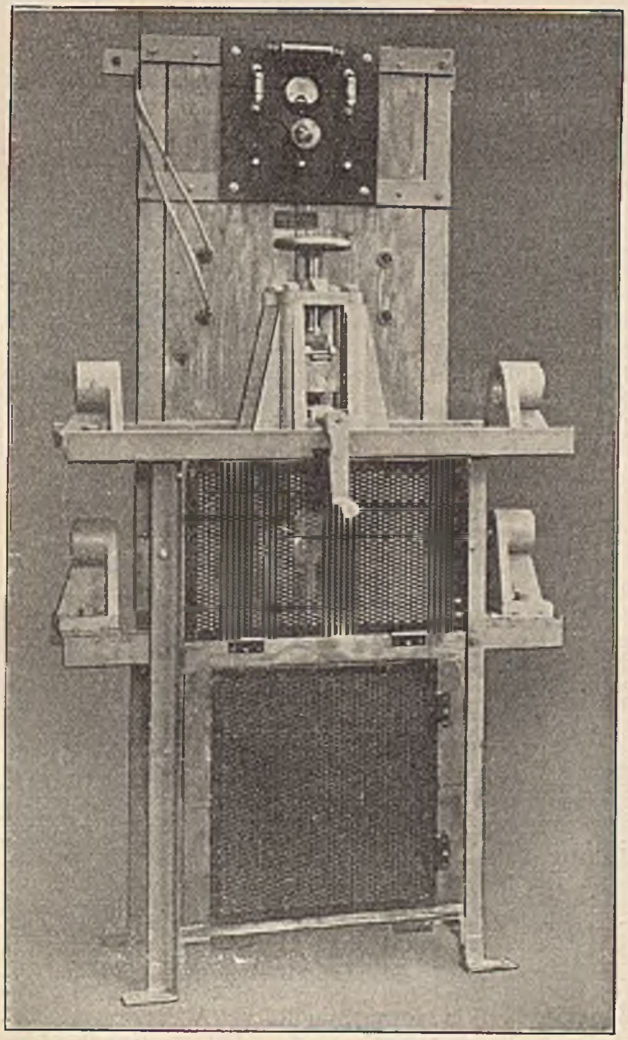


Fig. 1.

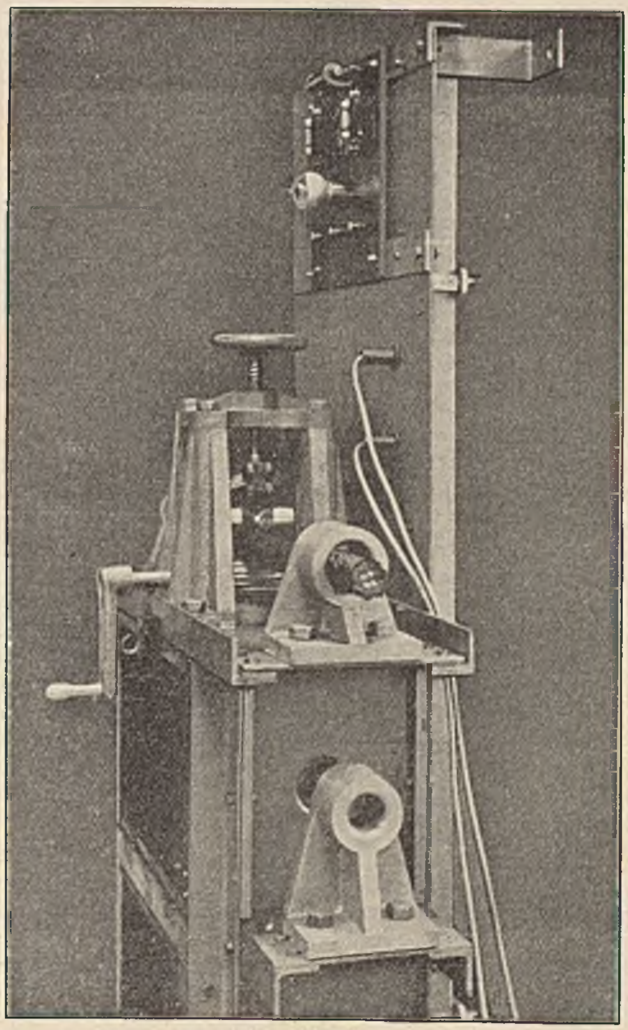


Fig. 2.

board, and pass it slowly through the press as shewn in Fig. 2. Immediately the fault is reached there is a deflection in the milli-ammeter owing to the pressure exerted upon the carbon in the fault and the cable can then be opened out at the exact spot where the fault or short really is. It will be readily seen that the same operation can be used for testing between conductors. The lamp immediately indicates the type of fault, whether it be a short circuit or a fault in the insulation.

In brief, the whole process is (a) to carbonise the fault on the high pressure side: and (b) to locate the fault on the low pressure side.

The machine has been rigorously tested under all conditions, and in every case successful results have been attained.

The makers, Messrs. Imeson & Finch, Ltd., offer to test at their Works any cable or portion of cable which may be giving trouble, and invite anyone to call who may wish to see tests carried out.

Notable Electric Winder Developments.

The Metropolitan-Vickers Electrical Co. Ltd. are able to report remarkably successful results for last year's work in electric winder plant, since in addition to installations completed, they received new orders for no fewer than twenty-two equipments, of which nine were Ward Leonard sets of 1000 h.p. or over. Of the Ward Leonard sets four are for lead mines in New South Wales, four for copper mines in Rhodesia, and one—a repeat order—for a colliery in this country. The other equipments include a.c. sets for gold mines of the Rand, copper mines of Spain, and collieries of Great Britain.

Two of the large Ward Leonard sets are of special interest in that they are designed for completely automatic control, the winder being started by means of a single push button from any one of four working levels; and the operations of acceleration, deceleration and decking are regulated by the automatic equipment in accordance with a predetermined schedule. The scheme is remarkable in several respects: notably, in the first place, in the provision of means of operation from a number of levels; also in the fact that by means of an automatic brake governor the winder is definitely and positively kept within its predetermined deceleration curve, the mechanical brakes being automatically applied to the necessary degree should the regenerative control of the motor not give exactly the pre-arranged schedule.

This automatic system of braking, and a new type of hydraulic slip regulator, are two notable recent developments made by the Company which are likely to have considerable influence on winder design. Brief explanatory notes on the two developments are given below. The favourable impression already made on users is shewn by the fact that both types of equipment are being included on no fewer than eight of the nine Ward Leonard sets of the orders mentioned.

In the automatic braking system, the braking effort is applied as a function of the speed change of the cages, compensation being made automatically for all variations of load, speed of travel, and other conditions. The use of this new principle gives the equipment the remarkable and highly desirable characteristics, that any given position of the brake lever will give a definite rate of retardation under all conditions, and that any desired rate of retardation can be obtained without shock.

The retardation under emergency conditions is also capable of accurate setting, a definite rapid rate of retardation being set for operation, if the cages are approaching the end of travel, and a relatively slow rate of retardation selected for operation if the cages are in an intermediate position. The system thus ensures any required stoppage in a reasonably short distance of travel, while eliminating the risk of sudden stoppages which are a cause of grave danger to passengers and plant.

The new slip regulator consists of a hydraulic coupling between the motor and the flywheel of the motor-generator set. The device is a development of the well-known Vulcan coupling which has been extensively employed for marine propulsion and industrial drives. It consists essentially of two main elements, an impeller wheel mounted on the motor shaft, and a runner wheel mounted on the flywheel shaft, with a casing in which a controlled supply of oil provides the working medium. The oil circulates under pressure and by varying the amount admitted to the coupling, the slip can be regulated to any desired value from, practically, zero to 100 per cent. The system is introduced as an important improvement upon the usual form of the slip regulation by means of resistance in the secondary circuit of the driving motor of the flywheel set.

Face Belt Conveyors.

Messrs. Mavor & Coulson Ltd., have just published a pamphlet dealing fully with the construction and performance of their standard pattern of face belt conveyor. After three years of extensive usage the value of the totally protected lower belt is plainly established: the belt life is 50 per cent. longer than with an open type conveyor. The electrical driving equipment possesses several unique and advantageous features: this and the adaptability of the complete conveyor system, together with the notable mechanical construction and design merit review at greater length. We hope to give an illustrated description next month, but in the meantime those more closely interested will doubtless get into direct touch with the makers.

Calendars, Diaries, &c.

We are pleased to acknowledge the receipt of many seasonable gifts including the following:—

Calendars from Anderson Boyes & Co., Ltd., Motherwell; Geo. S. Ikin & Son Ltd., Hotel Street, Bolton; Enfield Cable Works Ltd., Lincoln House, High Holborn, London, W.C. 1; British Insulated Cables Ltd., Prescot, Lancs.; The Liverpool Electric Cable Co., Linacre Lane, Bootle, Liverpool; Evershed & Vignoles Ltd., Acton Lane Works, Chiswick, London, W. 4; Haslam & Stretton Ltd., 53/55 Tredegar Street, Cardiff; Thor Lamps and Supplies Ltd., Thor Works, Tredegar Street, Cardiff; Callenders Cable & Construction Co., Ltd., Hamilton House, Victoria Embankment, London, E.C. 4; Petters Ltd., Yeovil; Steven Murray & Co., Ltd., The Viking Press, Yeovil.

Diaries and Desk Accessories from The United Steel Companies Ltd., Sheffield; John G. Stein & Co., Ltd., Bonnybridge, Scotland; Simplex Conduits Ltd., Garrison Lane, Birmingham; The Chloride Electrical Storage Co., Ltd., 137 Victoria Street, London, S.W. 1; Enfield Cable Works Ltd., Brimsdown, Middlesex; A. Reyrolle & Co., Ltd., Hebburn-on-Tyne; J. A. Crabtree & Co., Ltd., Lincoln Works, Walsall.