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The PRACTICAL ELECTRICAL ENGINEER

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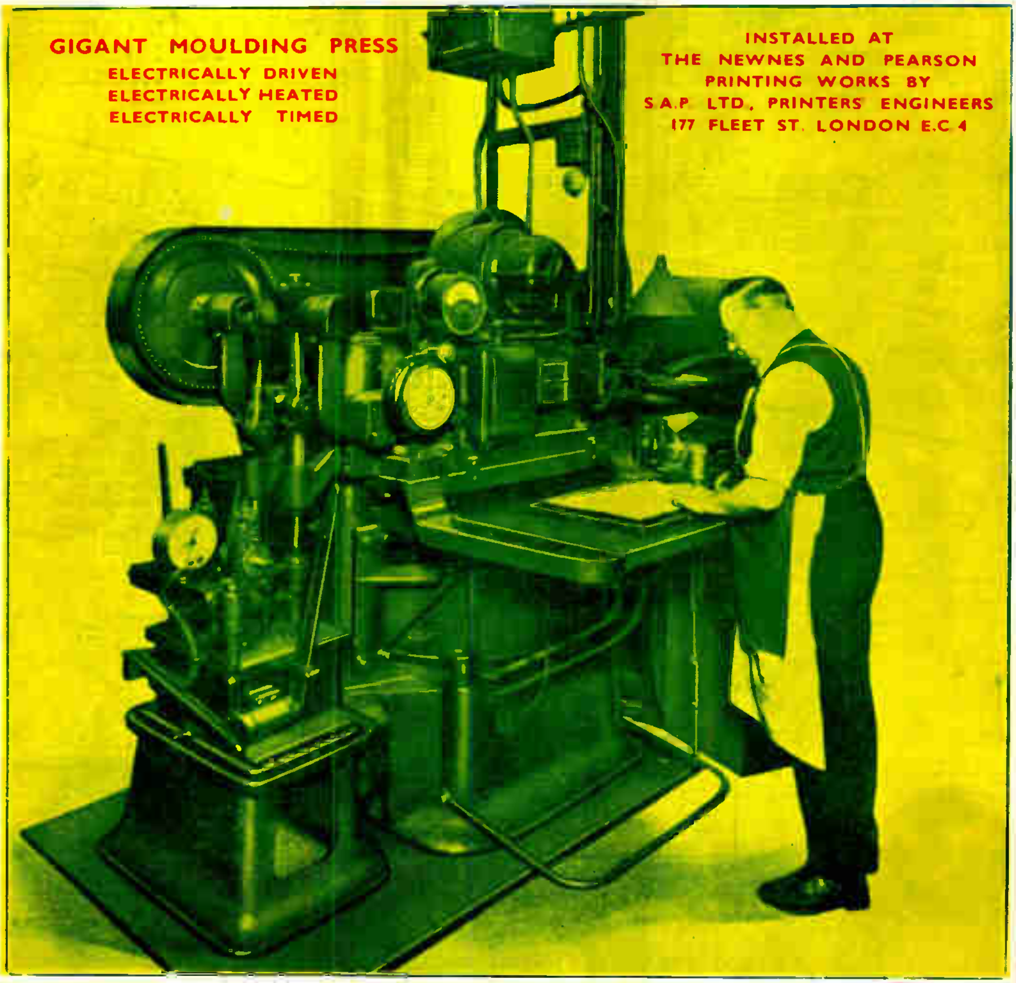

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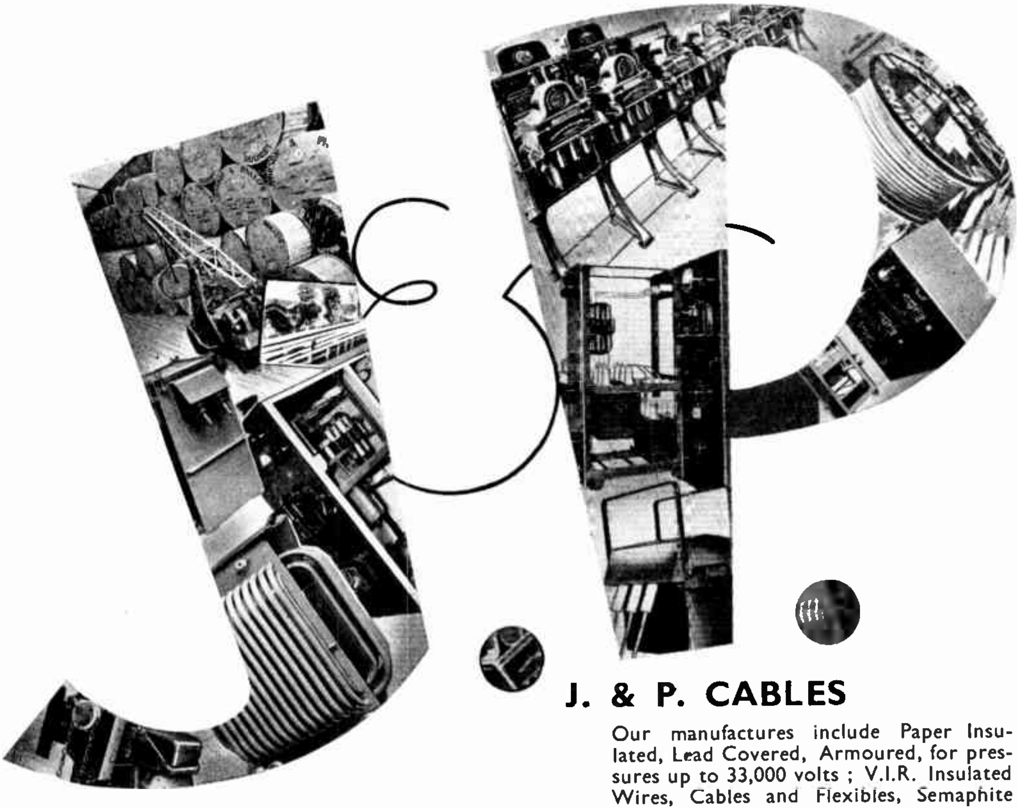

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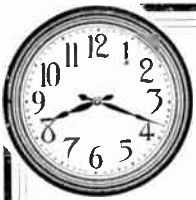


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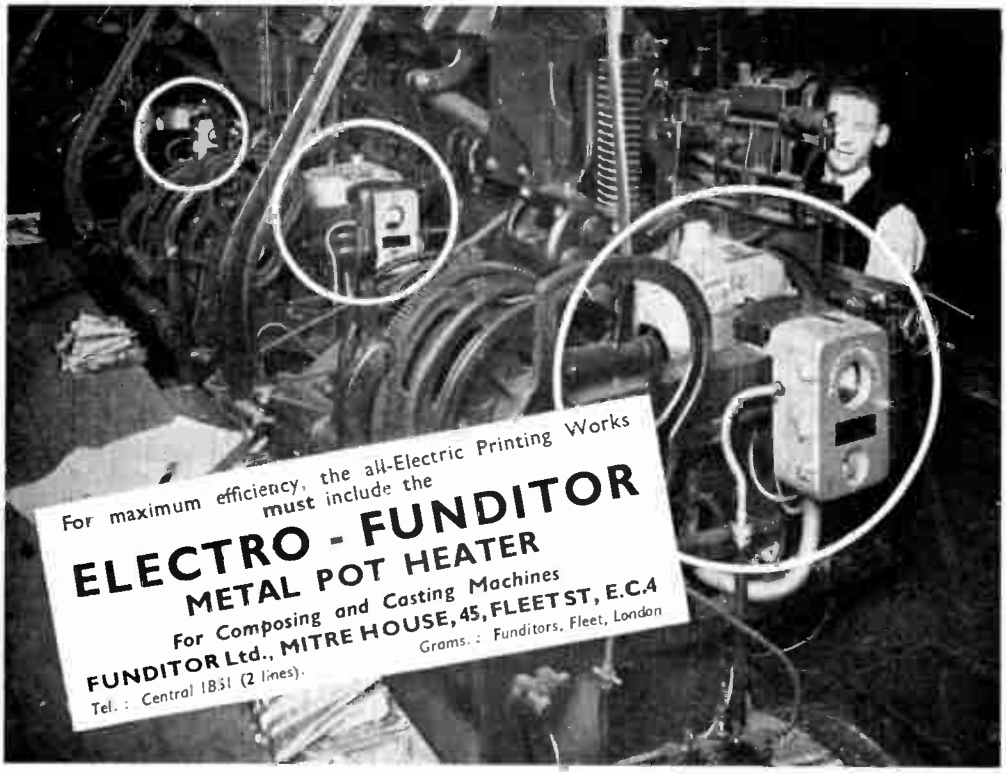

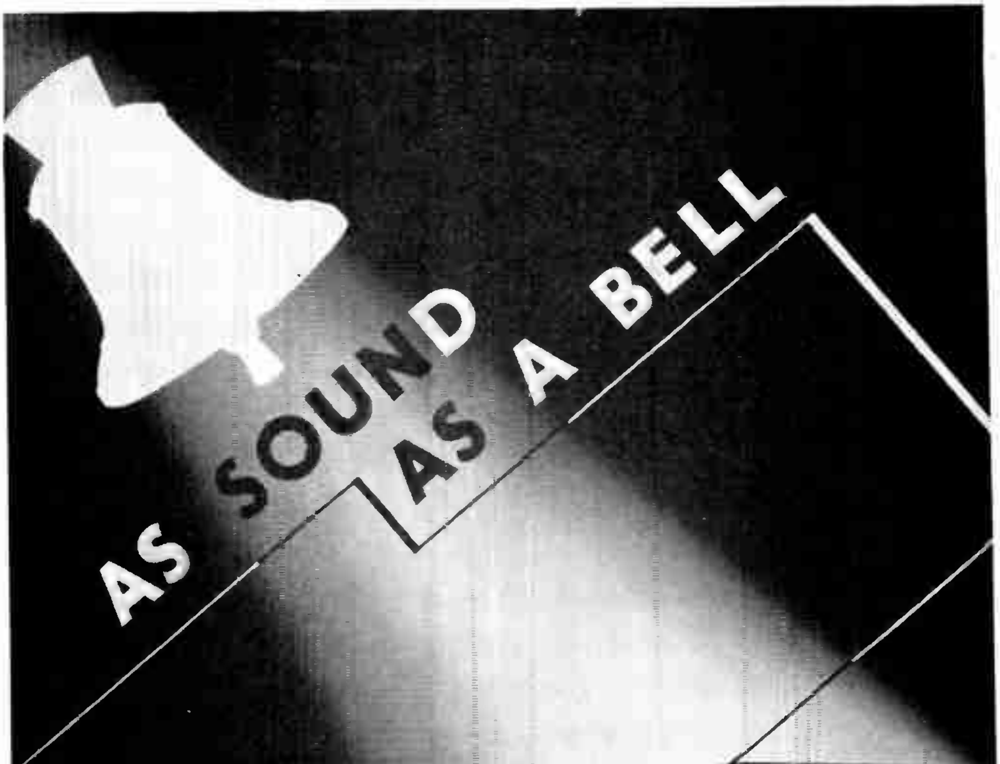
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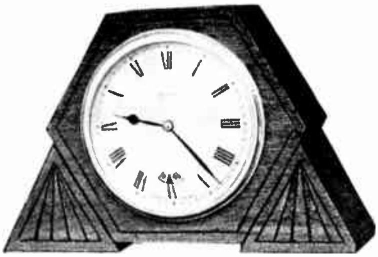

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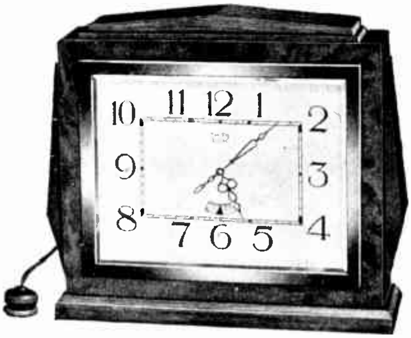

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The PRACTICAL ELECTRICAL ENGINEER

A MONTHLY SURVEY OF MODERN PRACTICE IN ELECTRICAL ENGINEERING

VOL. I JANUARY, 1933 No. 5

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IN a recent letter to a contemporary a correspondent states that after college training and an apprenticeship with a well-known company, the only prospects he could see for a young man in the electrical industry were as a canvasser for vacuum cleaners or water softeners. Are matters really as bad as that in the industry? Emphatically no.

In the electrical industry there is less unemployment than in most of the other important industries of the country. Here are a few typical figures :—

Coal Mining 34%, Iron and Steel Manufacture 48%, Marine Engineering 56%, Electrical Engineering 16%, Electrical Wiring and Contracting 17%, Electric Cable and Lamp Manufacture 10%.

The average unemployment in all industries is about 25%, so that the electrical industry is amongst the more fortunate.

Other bright spots in the industrial horizon are :—

Hosiery Manufacture 8.5%, Dressmaking 8%, Cocoa, Chocolate and Confectionery Manufacture 12%, Tobacco Manufacture 6.9%, Printing 10.5%, Tram and Omnibus Services 6.4%, Commerce, Banking, Insurance and Finance 5.6%, Laundries, Dyeing and Cleaning 9%, Paint and Varnish Manufacture 10.5%.

In every one of these industries there is scope for extended use of electric lighting, electric heating, and electric power.

An All-electric Printing Works.

A special feature of this issue is an account of the electrical equipment installed at the Newnes and Pearson Printing Works, where millions of periodicals are printed and bound each week. Electricity is used throughout the works, not only for lighting and power, but also for heating the monotype casting machines, the moulding presses, the nickel-plating vats and other appliances. Twelve years ago there was not a single electric lamp in the works. To-day the current consumption is in the neighbourhood of 1,000,000 units a year. And it is recognised as one of the most progressive in the country.

Fresh Fields to Conquer.

The photo electric insetter and the Gigant moulding press described on pp. 215 and 221 respectively, are two examples which give a glimpse of the still unexplored possibilities of electrical engineering when intelligently applied to the problems of the industrial works and factory.

Emergency (Dual) Lighting in Theatres and Cinemas

By A. T. Dover, M.I.E.E.

This article is of special interest to the Cinema and Theatre Engineer and the Electrical Contractor, more especially in those districts where there is no "Theatres main" to provide an alternative lighting supply.

Fig. 1.—Typical Installation of Safety Lighting Supply Equipment ("Keepalite" System) at a Provincial Cinema. (*Chloride Electric Storage Co.*)

Reference.—D, distribution box. K, "Keepalite" control panel. R, rectifier. S, switch and fuses. T, transformer for safety lights.

Note.—The connections are shown in Fig. o.

Compulsory Dual Lighting in Theatres and Cinemas.

In theatres, cinemas, concert halls and similar places of public entertainment a dual system of lighting from independent supply systems is compulsory by statute. This lighting must comply with the requirements of the local licensing authority.

Home Office Requirements.

The Home Office insists in its regulations: (1) that in any theatre or cinema there shall be an adequate number of safety or emergency lights which must be illuminated the whole time that the public is present in the building; (2) that these lights must be fed from a source which is entirely independent of that of the main auditorium lighting. In the majority of cases the main lighting is taken from the local electricity supply, which arrangement necessitates another separate source of supply for the safety lights.

London County Council Requirements.

In London the London County Council requires that in the auditorium or main hall the degree of lighting on each of the dual systems shall be not less than is sufficient to enable the public to see their way out of the premises at any time. In other parts of the building to which the public has access, good general lighting must be provided, but on neither of the dual systems must the degree of lighting be less than is sufficient for the public to see their way out of the premises.

How Independent Supplies are Obtained in London.

Formerly, in London, alternative supplies for the main and safety lights were obtained in many cases from two supply authorities operating independent (i.e., non-interconnected) generating stations. But on account of the unification scheme for London's electricity supply such an arrangement is not now always possible.

London's "Theatres Main."

In the case of the majority of the London West End theatres this specially approved independent source of supply takes the form of a special "theatres main," which is entirely independent of the ordinary distribution network (from which the main lighting is taken) and is fed from an independent source at the substation.

How an Alternative Supply is Obtained When Special Mains are not Available.

Where such special mains are not available a separate source of supply must be installed on the premises and for this purpose the storage battery is unequalled for reliability and economy. Fig. 1 shows a typical installation at a cinema.

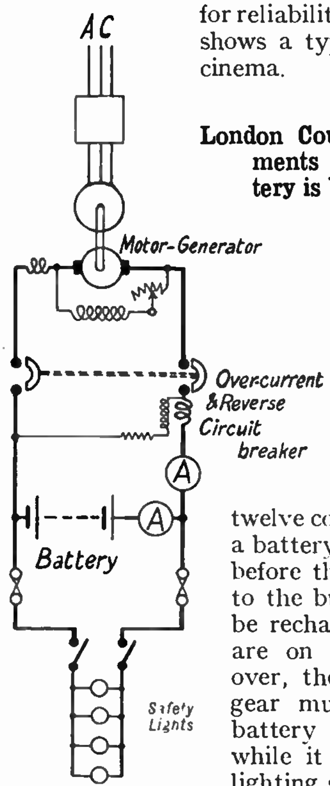


Fig. 2. — FLOATING BATTERY AND D.C. GENERATOR SYSTEM OF SUPPLYING SAFETY LIGHTS.

NOTE.—The end-cell regulating switches are not shown.

London County Council Requirements When a Storage Battery is Used.

Unless the Council agrees otherwise, any storage battery which supplies either of the dual lighting systems must be capable of maintaining the full load on that system for at least twelve consecutive hours. Such a battery must be fully charged before the public are admitted to the building, and must not be recharged while the public are on the premises. Moreover, the circuits and switchgear must be such that the battery cannot be charged while it is connected to the lighting system.

Subject to certain restrictions, the Council may accept "floating" or (in certain cases) "trickle-charged" batteries of a considerably lower capacity than that indicated in the preceding paragraph. In these cases the size of the battery is usually such that the full load on the lighting

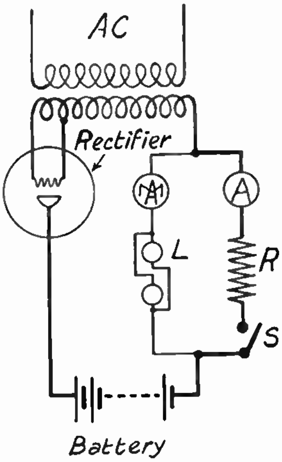


Fig. 3.—HOW THE TRICKLE AND HIGH-RATE CHARGING CURRENTS ARE OBTAINED FROM A RECTIFIER.

The trickle-charging current is adjusted to the correct value (read on the milliammeter) by the lamp resistances, L. The high-rate charging current is adjusted to the correct value (read on the ammeter, A) by the resistance, R, this circuit being controlled by the switch, S.

system which it supplies can be maintained for a period of three consecutive hours.

Floating Battery System of Supplying Safety Lighting.

A floating battery is one which, being fully charged, is connected in parallel with direct-current plant (generator or rectifier) and is normally inactive (i.e., it is neither discharging nor being charged), the voltage of the battery always balancing that of the generator.

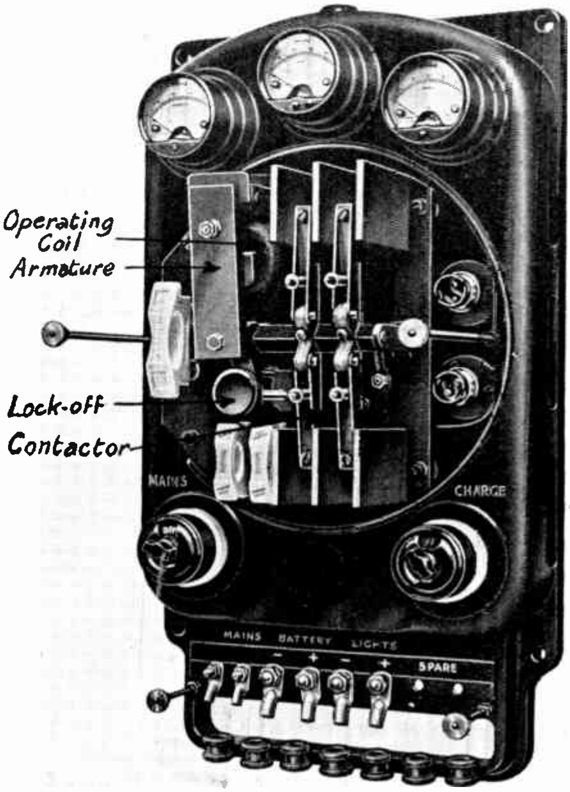


Fig. 4.—STANDARD " KEEPALITE " CONTROL PANEL WITH COVER REMOVED. (*Chloride Electrical Storage Co.*)

The cinema panel is fitted with a triple-pole contactor instead of the double-pole contactor shown in the illustration. The " mains " switch is a double-pole switch for isolating purposes. The " charge " switch is a single-pole switch for high-rate charging. The " lock-off " is a mechanical device for locking the contactor in the " off " or neutral position shown in the illustration.

Floating Battery and Rectifier.

As applied to a theatre or a cinema in London the battery floats across a rectifier which is connected to, and normally supplies, the safety or secondary lighting system. The rectifier is connected to the A.C. supply system which supplies the main lighting.

In the event of the supply failing, the safety lights are supplied by the battery without any interruption of the lighting. Upon the restoration of the supply the lighting is again supplied by the rectifier, and the battery again floats across the rectifier. The battery must, of course, be recharged at the earliest opportunity. This recharging is effected from the rectifier.

End-cell Switches.

End-cell or regulating switches are necessary in the battery circuit for the purpose of adjusting the number of cells in circuit so that in normal operation the voltage of the battery balances that of the rectifier. In some installations these switches are provided at *both* (positive and negative) ends of the battery in order that all the regulating cells may be brought into use by using the cells at the positive and negative ends on alternate days.

Floating Battery and Generator.

Some local authorities allow the battery to be floated in parallel with a D.C. generator which is driven by a motor receiving power from the mains from which the main lighting is supplied. In this case a reverse-current circuit breaker must be provided in the generator circuit to prevent the battery discharging into the generator in the event of the failure of the supply to the driving motor. Fig. 2 shows the scheme of connections. End-cell switches are also necessary in this case

TABLE I.—PARTICULARS OF BATTERIES FOR STANDARD CINEMA SAFETY LIGHTING EQUIPMENTS (" KEEPALITE " SYSTEM).

Equipment reference No.	Number of cells.	Voltage of emergency lighting circuit.	Ampere-hour capacity of Battery.			Total load in kW. which the battery can supply for—	
			1 hour discharge.	3 hours discharge.	10 hours discharge.	1 hour.	3 hours.
1	14	25	15	21	30	0.375	0.179
2	26	50	15	21	30	0.75	0.358
3	26	50	30	43	60	1.5	0.716
4	26	50	45	64	90	2.25	1.075
5	26	50	60	86	120	3.0	1.433
6	50	100	45	64	90	4.5	2.15
7	50	100	60	86	120	6.0	2.866
8	50	100	90	129	180	9.0	4.3

Trickle - charged Battery System of Supplying Safety Lighting (" Keepalite " System).

In this system the safety lighting is normally fed from the public supply system which supplies the main lighting. But an *automatic change-over switch* is provided which will instantly switch the safety lights over to a standby battery, which is normally maintained continuously in the fully charged condition by trickle charging. After an emergency discharge the battery must be given a quick recharge at the normal rate.

The battery must be of sufficient size to maintain the safety lights for a period of three hours.

With an A.C. supply system, low voltage safety lights are used, which are normally supplied from a transformer.

This system is used in a large number of provincial theatres and cinemas, and a typical installation is illustrated in Fig. 1. Particulars of the batteries for standard equipments are given in Table I, and the ratings of the transformers for these equipments are given in Table II.

With a D.C. supply system, however, the safety lights and the battery supplying them must be suitable for the mains voltage. Difficulties may then be encountered in the charging arrangements unless a three-wire supply system is available.

TABLE II.—RATING OF TRANSFORMERS FOR CINEMA SAFETY LIGHT CIRCUIT, WITH BATTERY EQUIPMENTS GIVEN IN TABLE I.

Equipment Reference No. in Table I.	1	2	3	4	5	6	7	8
Continuous Rating of Transformer(volt-amps)	200	375	835	1250	1500	2500	3000	4500

Trickle Charging.

This is a method of maintaining a fully charged standing battery in the fully charged condition by passing a very small charging current continuously (i.e., *day and night*) through the battery. The current must just balance the losses (e.g., self discharge due to surface leakage, gradual sulphation, etc.) which occur in the particular battery on open circuit.

By these means any tendency for the electrolyte to combine with the active material of the plates, and so cause sulphation, is counteracted so effectively that the plates never become sluggish, and retain their full capacity for an indefinite period.

Current Required for Trickle Charging.

The current required for trickle charging is very small—only a few milliamperes in some cases—as a modern Planté type stationary battery does not lose more than 2 per cent. per day of its ampere-hour capacity at the 10-hour rate. Thus, with a 90-ampere hour battery (10-hour rate) having an open circuit loss of 2 per cent. per day, the loss of ampere-hour capacity during 24 hours would be

$$\frac{2}{100} \times 90 = 1.8$$

ampere hours, which must be compensated by the ampere-hours supplied by the charging current. Hence, the charging current $= 1.8/24 = 0.075$ ampere, or 75 milliamperes.

In practice, the current is usually fixed slightly on the liberal side to take care of variations in the open circuit losses. The correct value may be ascertained by observation of the specific gravity, voltage, and gassing of the cells, as explained in the later paragraphs on maintenance.

Charging Arrangements.

The charging arrangements will depend upon the size of the battery and the nature of the main supply.

Charging from A.C. Mains with Rectifier.

When the main supply is alternating a rectifier outfit is employed to provide both the trickle charging current and the high-rate charging current for the standard equipments given in Table I.

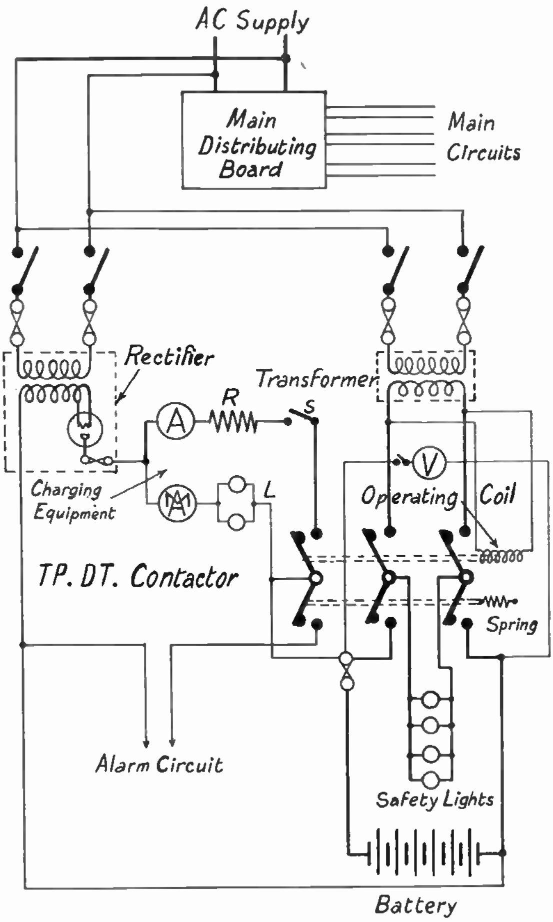


Fig. 5.—Connections of "Keepalite" A.C. Cinema Equipment.

How the Trickle and High-rate Charging Currents are Adjusted.

The trickle charging current is adjusted to the required value by suitable series resistances (usually lamps), and the high-rate charging current is obtained by switching a resistance in parallel with the trickle charging resistance. Fig. 3 shows the general scheme of connections when a valve rectifier is employed.

"Keepalite" Automatic Switch and Control Panel.

The automatic switch in the "Keepalite" system of safety lighting fulfils two functions, viz.: (1) It connects the safety lights to the battery when the normal supply fails; (2) it reconnects the battery to the charging circuit when the main supply is restored and maintains the battery continuously on trickle charge during normal conditions.

A typical control panel is illustrated in Fig. 4. This type of control panel is used in all standard "Keepalite" equipments, and a slightly modified form is used in the cinema equipments.

Connections of "Keepalite" Cinema Equipment for A.C. Mains.

Fig. 5 shows the connections of a standard cinema equipment in which a transformer is used to supply the safety lights. In all these cinema equipments the automatic switch takes the form of a triple-pole double-throw contactor, two of the poles being used for switching the safety lights from the transformer to the battery, and the remaining pole for switching the charging circuit and controlling an alarm circuit.

How the Automatic Switch Works.

The operating coil of the contactor is permanently connected across the secondary winding of the transformer which normally supplies the safety lights. Hence, as long as this supply is maintained, the armature will be attracted to the pole piece, the upper moving contacts will make contact with the upper set of fixed contacts, and the lower contacts will remain open. Thus the safety lights will be supplied from the transformer, and the battery will be trickle charged all the time that the main supply is maintained on the operating coil. But immediately this supply fails, the contactor will drop over to the lower contacts, and the safety lights will be connected to the battery. At the same time an alarm circuit will be closed to indicate that the main supply has failed. When the supply is restored the contactor will switch the battery over to the charging contacts. The battery may then be given a high-rate charge, if necessary, by closing the " charge " switches.

The trickle and high-rate charging currents are indicated on separate ammeters.

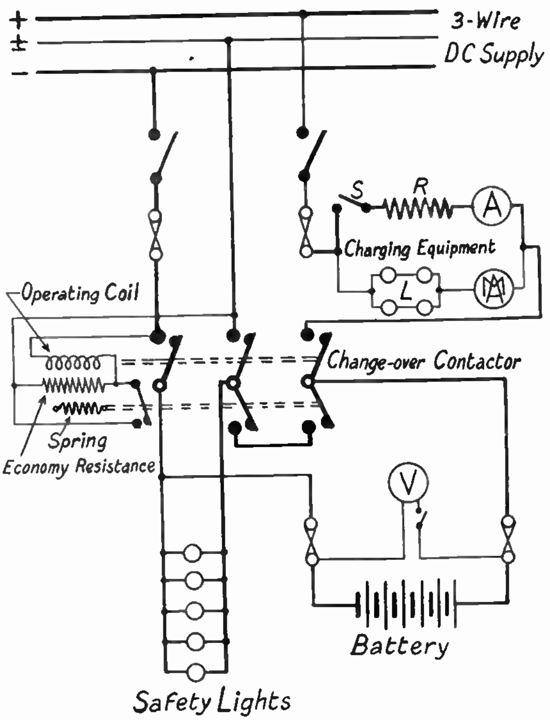


Fig. 6.—CONNECTIONS OF " KEEPALITE " D.C. CINEMA EQUIPMENT FOR THREE-WIRE SUPPLY.

Connections of "Keepalite" Cinema Equipment for Three-wire D.C. Mains.

Fig. 6 shows the connections when a three-wire D.C. supply is available. In this case the safety lights are normally connected between one of the outers and the neutral, and the battery is of this voltage. Charging is effected from the outers of the supply system.

How the Trickle-charging and High-rate Charging Circuits are Arranged.

The trickle-charging and high-rate charging circuits are arranged similar to those in the A.C. equipment, but the series resistances are of higher value.

How Energy Consumed by the Operating Coil is Reduced.

In order to reduce the energy consumed by the operating coil, the winding of this coil is designed so as to close the contactor when it is excited with the mains voltage, and, after closing, a resistance is connected in series with the winding to reduce the current to such a value as to hold the contactor in the closed position.

The Auxiliary Switch.

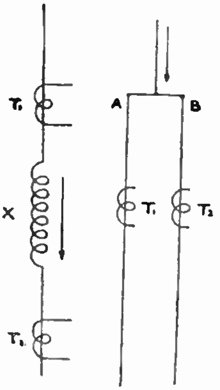
An auxiliary switch is required on the contactor to short-circuit this resistance when the moving contacts of the contactor occupy the lower position (i.e., when the main supply is "off," and the safety lights are supplied from the battery).

THE PROTECTION OF ELECTRICAL PLANT AND APPARATUS

By H. W. Richardson, B.Sc., M.I.E.E.

The rapid development of electric power systems has resulted in an increasing demand for effective systems of protection. In this article Mr. H. W. Richardson describes the G.E.C. system of protection which is based on McColl patents

A GENERATION ago the homely fuse wire and the earlier forms of circuit breaker with automatic tripping device were the standard forms of protective apparatus for electrical plant and systems. The best testimony to their value on low-tension circuits lies in the fact that after many years of reliable service, these two methods are still widely in use for such circuits carrying small quantities of power. But as a result of the rapid rate at which electric power systems have developed, leading to ever higher voltages and ever increasing quantities of power, the need for altogether more effective forms of protection has arisen. In consequence, what is in effect a new branch of electrical engineering has been created, for the science and practice of protecting adequately the plant and apparatus used in modern practice is a very wide subject, and one which younger electrical engineers would do well to study.



Two Elementary Circuits for Protection.

On the left, the elementary principle of balanced protection; on the right, the method of parallel feeder or split conductor protection.

Why Modern Conditions Demand a High Degree of Protection.

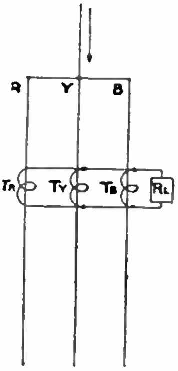
It is not always appreciated why modern conditions demand so high a degree of protection as is considered necessary by those who have made a study of the subject. There has been a tendency in some quarters to regard sytems of protection in vogue to-day as introducing altogether unnecessary complications. But such opinion would not appear to have given sufficient consideration to the alternatives to really effective forms of protection. For instance, if a 50,000 kw. turbo-alternator were not protected against all untoward contingencies that might arise, many thousands of pounds worth of damage could conceivably be done within comparatively few seconds. Moreover, capital need not be locked up in unproductive standby plant, if continuity of service can be reasonably ensured by the adoption of proper protective apparatus.

A Typical Protective System.

It would require a bulky volume to describe the many systems of electrical protection which have been devised, and the almost countless forms of relay introduced during the last few years. It is therefore proposed to try and give an idea of modern protection by describing some of the methods of application of one well-known protective system to the equipment used in a modern power-supply system. The protective system chosen for description is that developed by The General Electric Company, Ltd., which is based upon McColl patents.

Common Conditions Against Which Protection Must be Provided.

In order to be in a position to understand the application of such a system, it is necessary first to review briefly what are the most common conditions against which protection must be provided and the fundamental method of dealing with them. Common faults comprise overloads, reverse currents, faults between phases and earth, failure of excitation,



Balancing Principle Applied to Three-phase Circuit.

etc. These arise in a variety of ways, in the majority of cases due to faulty insulation with consequent leakage. Many leaks are of a very small order when they first occur, but the extent of the leakage often develops rapidly and the operation of suitably designed protective gear will isolate the section of the system containing the fault before a dangerous state of affairs is reached.

Underlying Principle of Modern Protective Systems.

The underlying principle upon which most modern protective systems are based is that, providing there is no fault in the apparatus to be protected, the current entering the apparatus is the same as that leaving it. If current transformers are connected on both sides of apparatus and their secondaries connected by pilot wires to a relay, so long as the apparatus is sound and there is no fault in it a state of balance exists and no current will flow through the relay.

What Happens When a Fault Occurs.

Immediately a fault occurs in the apparatus there will be a difference in the current flowing into and out of it, with a consequent upsetting of the balance in the secondary circuit so that a current will flow through the relay, thus operating it and causing the isolation of the faulty apparatus. The elementary form of circuit based on this principle is illustrated, the pilot wires being omitted for the sake of simplicity. "X" in this diagram may be either a phase of a generator or a feeder. A variation of this elementary principle is furnished by the protection of parallel feeders or the split conductor system is also shown. The load will normally be shared between the two conductors A and B, a state of balance thus existing. Should a fault develop in either of them an excess current will pass into the damaged conductor, thus upsetting the balance of the current transformers and operating the relay.

Split Conductor System.

The use of the split conductor obviates the need for pilot cables, but—against this advantage—special split cables are involved and special switches. The split conductor system is, however, in use in a good many places.

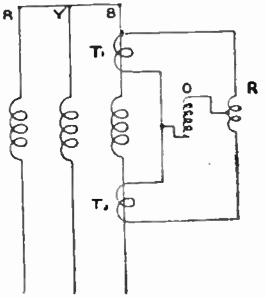
Balancing of Three Phases.

Another common application which will make clear the further application of the balancing principle is furnished by the balancing of three phases as illustrated. If no fault exists the sum of the currents is zero, and no current will flow into the relay. Immediately the balance is upset by leakage the relay operates.

In giving these three simple illustrations of balanced protection it must not be assumed that they are applicable in such elementary fashion in practice, or that any one of them necessarily represents all the protection required for the part of the system under consideration. For instance the method shown obviously affords no protection against faults between phases, which require special attention. So far we have considered only the fundamental principle.

The Principle of Balanced Protection.

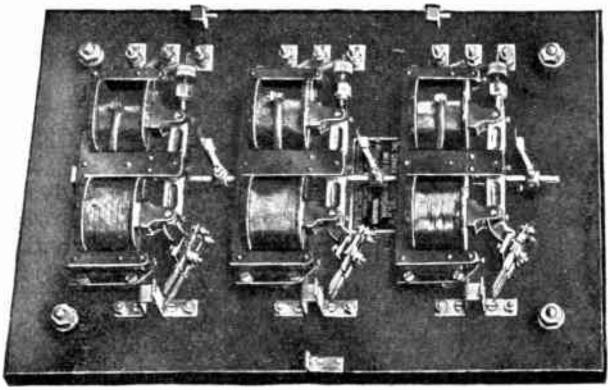
The G.E.C. system of protection, incorporating McColl patents, which has been chosen as an example for the purpose of this article, is based upon this principle of balanced protection. The great feature of the system lies, however, in its introduction of the biassing principle, the addition of which has so tremendously increased the value of the balancing principle.



The Biasing Principle Added to Balanced Protection.

Two Important Properties.

Before the great importance of biasing can be appreciated, it will be necessary to discuss two important properties of a protective scheme. These are (1) sensitiveness; and (2) stability.



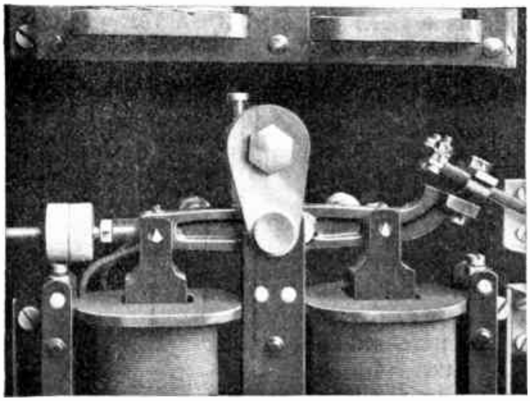
Beam Relay with Cover Removed.

Sensitiveness.

Considering first, sensitiveness, this property may be defined as the ratio which the lowest fault current which operates the relays bears to the normal current which flows in the circuit protected. This ratio is expressed as a percentage, and it is obviously of the greatest importance that the sensitivity should be as low as is possible, in order that the faulty section of the apparatus shall be isolated before the fault has developed sufficiently to cause any serious trouble.

Fault on a 20,000 kVA. Turbo-alternator.

How important this point is may be grasped readily by considering the case of a fault on a 20,000 kVA. turbo-alternator. Should the relays be capable of tripping at 20 per cent. of normal current, i.e., if the sensitivity is not less than 20 per cent., a fault may develop between phases involving as much power as 2,300 kVA. before tripping. It will thus be realised that a value of sensitivity of much less than this figure is desirable in the case of turbo-alternator protection.



" Topple " Weight Added to Beam Relay.

On the other hand there is a limit to the minimum value of sensitivity which is obtainable.

Minimum Value of Sensitivity.

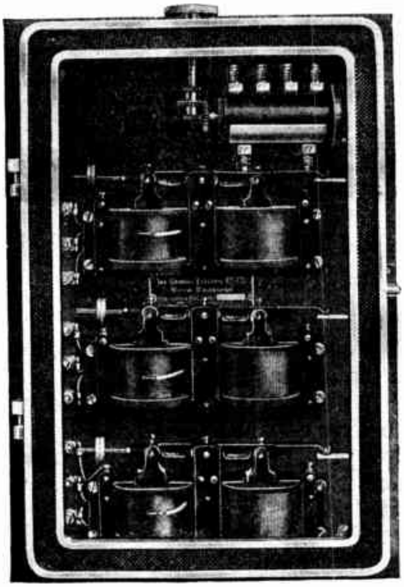
This arises due to capacity and magnetising currents which flow into feeders and transformers. It is only at no load or very light loads that these currents assume any significance, but clearly it must not be possible for them to operate the relay. In consequence, the fault current which will be sufficient to operate the relay must be just greater than that due to capacity and magnetising effects.

Stability.

We now pass to the second important property of a protective scheme referred to above, namely, stability, the function of which is very closely linked up with sensitiveness. Stability is that property of a circuit in virtue of which the relay will not operate to isolate a section of the system when there is no fault on that section. Lack of stability proved one of the greatest bugbears in the early days of protective schemes, and considerable ingenuity was necessary before protective schemes were available which could be described as truly stable.

Why Stability Was Difficult to Obtain.

It was not that stability was difficult of attainment for normal conditions of load, but when short circuit conditions arise currents of as much as 20 times the normal may flow passing right through the apparatus protected. The effect of such through currents on the current transformers may cause different currents to flow of higher value than the fault setting of the relay, in spite of the fact that the currents are perfectly balanced at normal loads. In this way a section of the apparatus might be isolated when there is no fault in it. Stability, then, is the ratio of the highest through current which will permit of the system being stable to the lowest fault current that will cause fault tripping.



DRUM CONTACT BEAM RELAY.
With cover in position.

A Cause of Inefficiency in Protective Systems.

At first sight it must seem that sensitivity and stability are properties which cannot both be possessed by a protective system, for if a circuit is to be stable it must have a high fault setting, and this is incompatible with sensitivity. It is in this respect that many systems of protection have been inefficient. In some cases, in order that the system might be rendered stable, it has been necessary to have a fault setting of the order of double the normal load. In other words, the sensitivity would be 200 per cent.

A System Which Combines Minimum Sensitivity With Maximum Stability.

The outstanding feature of schemes based upon the McColl patents is that they are able to combine minimum sensitivity with maximum stability, and thus a sensitivity of 5 per cent. to 10 per cent. is regarded as a standard for the G.E.C. system of protection, while the stability might be regarded as infinite for reasons which will shortly be apparent.

How This is Obtained.

This attainment of minimum sensitivity and maximum stability has been made possible by the application of the principle of biasing. Without the coil R, the diagram given would represent the balanced protection of one phase of a generator. But a biased relay is used consisting of the operating coil O, a restraining coil R and a biasing provision. This relay operates when the effect of the excess current flowing through O overcomes the effect of the load current in R. Thus the excess current required to operate the relay is varied automatically with the load and consistent protection is given at all loads. The biasing is usually provided by employing a beam relay, the degree of bias depending upon the relative numbers of turns upon the coils. A typical beam relay is i lustrated here.

Fault Current Will Increase in Proportion to Load Current.

The truth of the statement made above that the stability of a protective system employing the biasing principle might be regarded as infinite is now clear, for however great the load current may be, the fault current will increase in proportion and thus indiscriminate tripping will not be effected.

Construction of the Beam Relay.

As the beam relay is the fundamental item of apparatus in the system under discussion its construction is of practical importance. Its main features are evident from the photographs.

The operating and restraining coils together with the beam are securely built up on the laminated iron circuit, which acts as the basis of the apparatus. The beam is of aluminium, and is fitted with knife-edge pivots.

Terminals and Trip Contacts.

Both the terminals and the trip contacts are mounted directly on an enamelled slate base. The moving contacts, usually attached to the beams, consist of laminated brushes of silveroid, which has been found to be the most satisfactory metal for the purpose.

Generator and Transformer Protection.

For generator and transformer protection, the main pivot is in the middle of the beam, the bias being produced by suitably proportioning the turns of the operating and restraining coils. For feeder protection the pivot is displaced a small distance from the centre line, in order to give the desired bias in favour of the restraining coil.

Relays.

Relays may be made self-resetting or hand-resetting. For the latter purpose, a vertical resetting rod is fitted which is clearly indicated.

Relays are frequently required to make three or more contacts, in order to close the trip circuits for all the protective operations directly. Or it may be desired that a relay which has tripped shall continue to effect the full pressure even after the current has been cut off.

Why a "Topple" Weight is Used.

For this purpose, a very simple and effective addition is made to the standard relay, consisting of a "topple" weight, which rotates on centres formed at the ends of the main pivot. When the beam is in the "off" position, the supporting screw of the weight rests lightly upon the restraining side of the beam, the centre of gravity of the weight being just behind the dead centre. But immediately after the beam begins moving, the weight passes over the dead centre, and comes right down upon the operating side, producing the following effects:—

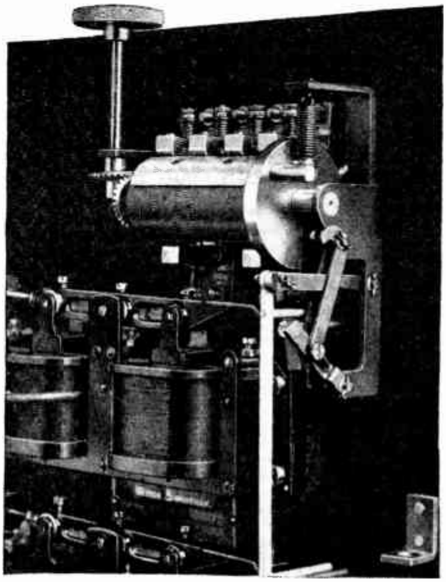
(1) Greatly magnifying the pressure on the contacts;

(2) Increasing the speed of operation (in the case of very small faults);

(3) Maintaining the pressure after the main circuit has been tripped;

(4) Indicating which relay and which phase have caused tripping.

The pressing of the usual resetting button is sufficient to restore the whole to the "off" position.



Drum Contacts and Sensitive Lever System for Beam Relay.

Drum Contact Beam Relay—

Another form of beam relay giving identical effects with those described above is the drum contact beam relay.

In this model the contacts are not mounted at the ends of the beams but press upon a vertical rod, which releases a substantial contact drum engaging with any desired number of fingers.

Although the drum is rotated by a powerful spring, it is effectively tripped by the lightest touch of the beam through the medium of an ingenious system of compound levers.

—And its Uses.

By the use of this type of relay, it is possible to open certain contacts in addition to closing other contacts when tripping occurs. The standard drum makes provision for the opening of four contacts as well as for the closing of four more if desired.

AN ALL-ELECTRIC PRINTING WORKS

By W. T. KENNEY, Chief Engineer of the Newnes & Pearson Printing Co., Ltd.

THE present article, whilst it has a particular interest for engineers in the printing industry, is of exceptionally wide interest to electrical engineers as a whole.

Some World Famous Names.

It deals with the electrical equipment of one of the largest and most progressive magazine and periodical printing works in the world where *The Radio Times*, *Tit-Bits*, *The Strand Magazine*, *Pearson's Weekly*, *Pearson's Magazine*, *Novel Magazine*, *John o' London* and many other famous publications, having a total circulation of over 250 million a year, are printed and bound.

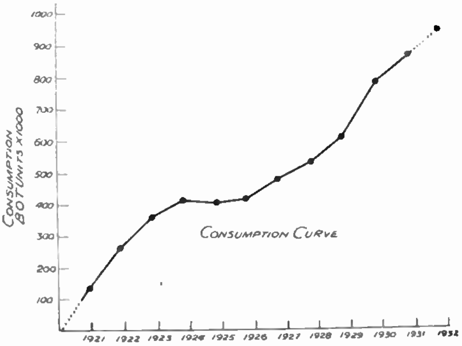
Twelve years ago these works with a total floor area of 23,000 sq. ft. were lighted by gas and the machines were driven by line shafting from steam engines. To-day the works, now with a total floor area of approx. 90,000 sq. ft., are electrically driven throughout. Electric lighting and heating is used throughout.

How Much Electricity it Takes to Print One Copy of Tit-Bits.

As the yearly consumption is about 900,000 units each periodical produced in the works requires an average of about 4 watt hours of electrical energy to be expended in lighting the works and offices, driving the presses, heating the casting machines in the foundry and driving the conveyers, trucks, hoist blocks and other appliances which are used in a modern printing plant.

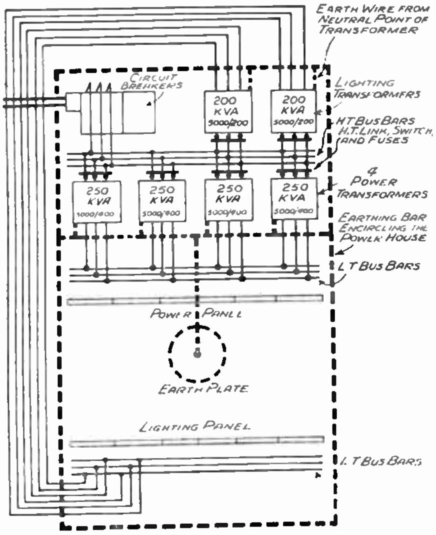
Four watt hours of electricity is $\frac{1}{250}$th part of a unit, and at present-day prices of electricity it represents about $\frac{1}{250}$th part of a penny.

This is a very striking example of the economy which can be effected by the use of electricity as a motive power, in combination with modern printing machinery and efficient works organisation.



CURVE SHOWING INCREASE IN UNITS CONSUMED, 1921-1932.

In 1921, the total units consumed was 55,000. It is estimated that for the year ending 31st December, 1932, the consumption will have exceeded 950,000 units.



TRANSFORMER AND SWITCH ROOM.

Note earthing bar encircling the room. On the lighting panel the L.T. busbars are in duplicate. See also the diagrams on pages 216 and 217.

TRANSFORMER AND GENERATOR ROOM.

The Incoming Supply—5,000 volts, 3 ph., 50 cycles.

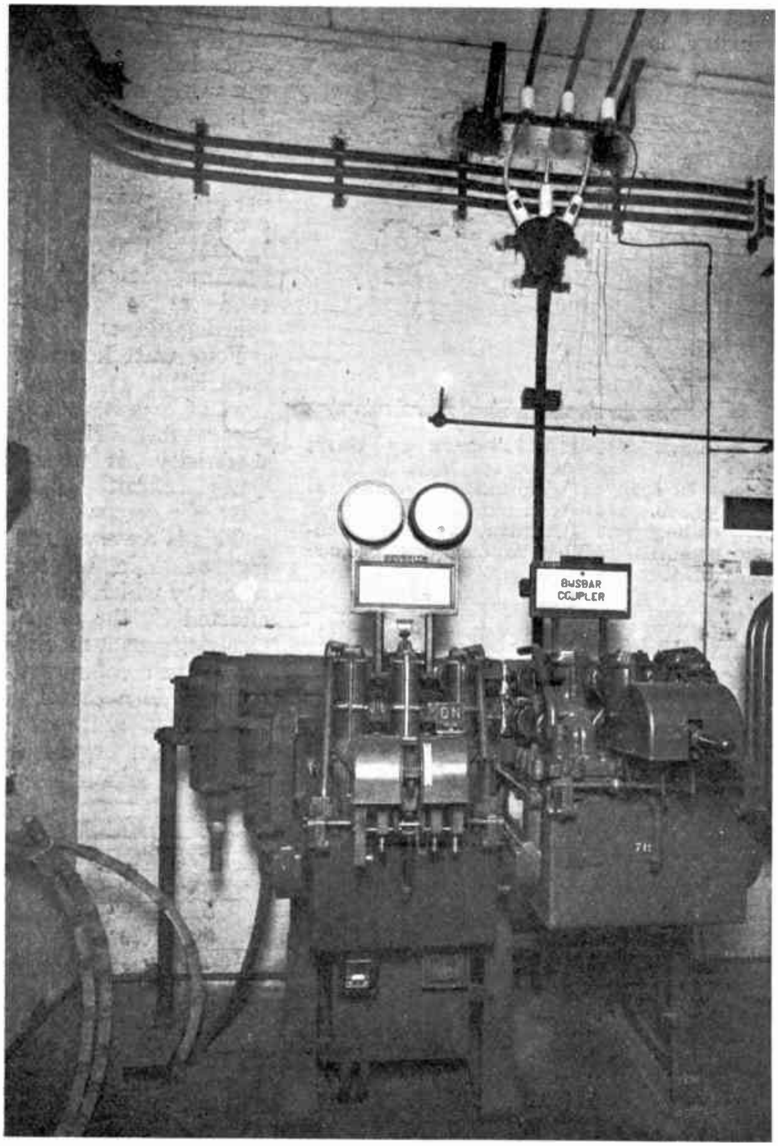
Current is obtained in bulk from the Notting Hill Electric Supply Company, Limited, at a pressure of 5,000 volts, 3-phase, 50 cycles. The incoming feeders consist of two 3-core .15 sq. in. section copper paper-insulated steel wire armoured cables laid in troughs and are connected to the supply company's switch in Newnes and Pearson's premises, one acting as a spare to the other in case of breakdown.

Main Circuit Breakers.

The company's circuit breakers referred to above are of the Reyrolle heavy industrial ironclad type, of the draw-out pattern. The switch is housed in the same room as the transformers.

Six Transformers—4 for Power, 2 for Lighting.

These belong to the Printing Company and are 6 in number—4 for power and 2 for lighting loads. Each of the four power transformers are of 250 kVA., 5,000/400 volts, 3 ph., 50 cy. capacity. The two lighting transformers are respectively 200 kVA. and 100 kVA. with ratio of 5,000/200 volts, 3 ph., 50 cy.



THIS SHOWS THE REYROLLE INCOMING SUPPLY MAIN SWITCH.

The Notting Hill Electric Supply Company's main (in duplicate) can be seen on the left. Note the busbar coupler, which will "loop in" the station on to the grid ring. The circuit breakers are rated at 300 amperes and have a breaking capacity of 100,000 kVA.

The H.T. Busbars—Tinned Copper Strip.

The H.T. busbars, to which are connected the cables from the supply company's switch, are fixed above and between the two banks of transformers and are of solid tinned copper, mounted on porcelain insulators.

The H.T. Panels, Equipped with Liquid Fuses.

Between the H.T. busbars and the H.T. side of the transformers are mounted the H.T. switch fuse panels. Each consists of a sheet steel panel on which are mounted the 3 isolating link switches and 3 Empire liquid fuses. The liquid fuses are supplied by the Electric Control Company, Limited, of Brighton, their main function being to protect the H.T. windings against a heavy surge from the supply company's side of the oil switch, as these fuses operate in a very small fraction of a second, much quicker than the oil switch would take to trip.

H.T. Connections to Transformers.

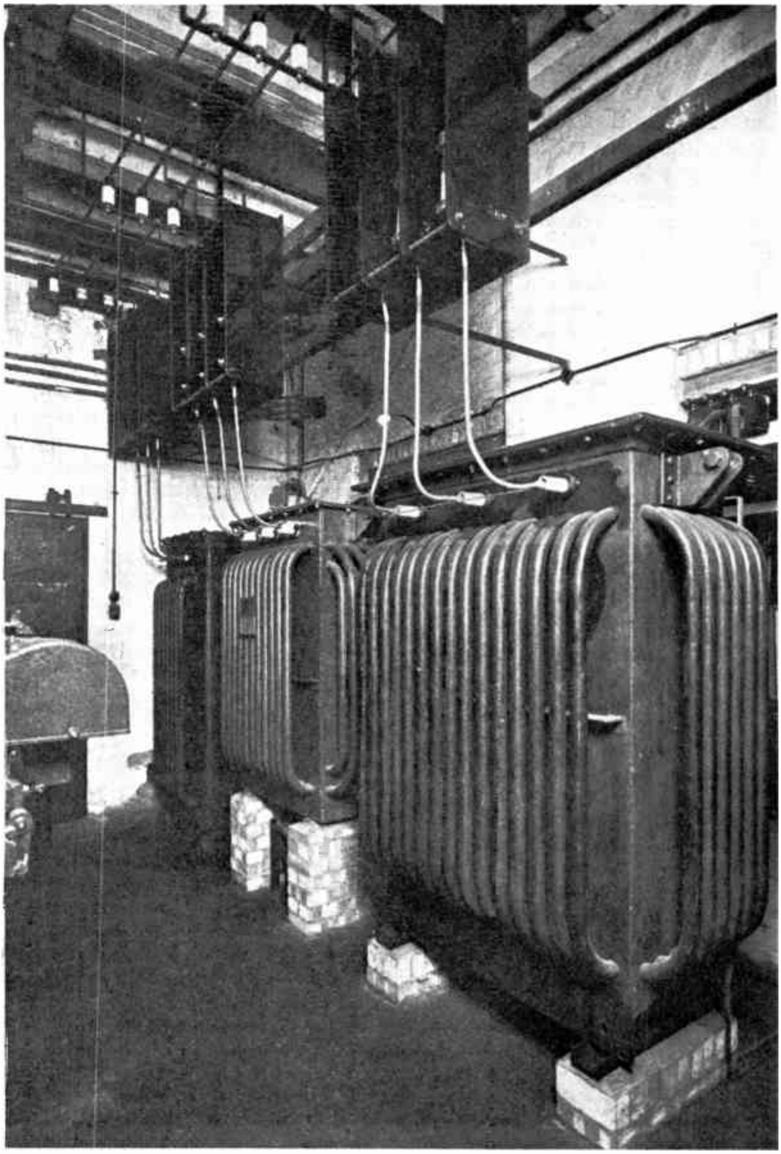
Tappings are taken from the H.T. busbars to the live side of the link switches on these panels and from the bottom clips holding the liquid fuses, lead covered 6,600 volt V.I.R. cables are connected through porcelain bushes to the H.T. connections in the transformers.

The Power Switchboard.

This consists of 6 sheet steel panels, all mounted on rigid angle iron framework. Four panels control the L.T. incoming 400 volt supply from four 200 kVA. transformers and 2 panels control 6 sets of outgoing triple pole feeders to the unit ironclad switch fuse panels described later.

The Power Feeder Panels.

The panels controlling the incoming supply for power are fitted with oil immersed switchgear and fuses, ammeter



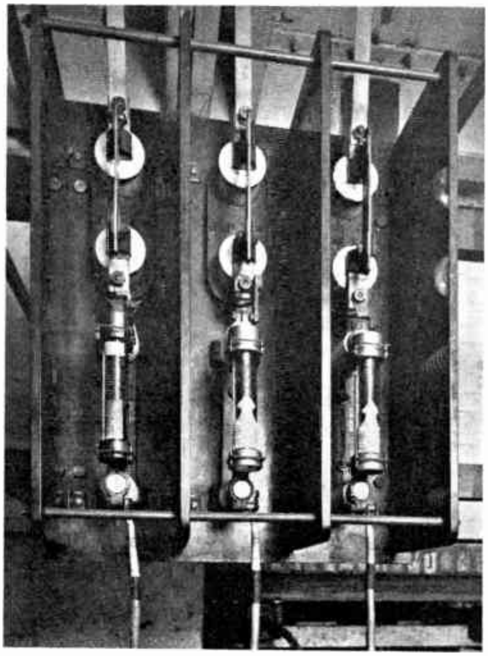
A General View of the Transformers.

Four power transformers and two lighting transformers are installed. The down leads from the H.T. busbars pass to the transformer terminals through link switches and liquid fuses.

and voltmeter and all necessary busbars at back. The feeder panels have the triple pole link switches all mounted at back of panels, the fronts being plain except for a P.F. meter and periodicity meter. Solid copper busbars run the whole length of these panels, to which the copper connections from the switches are connected.

Lighting Panel.

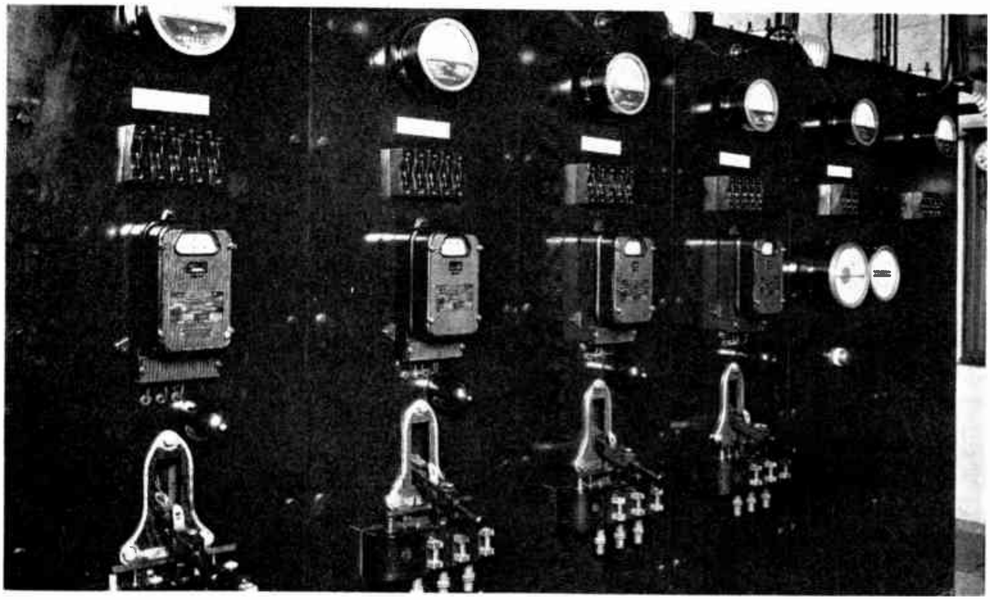
This consists of six slate panels, two of which control the incoming 200 - volt supply cables from the 100 kVA. and 200 kVA. transformers, and the four others the outgoing feeders to the triple pole distributing fuse boards situated in suitable positions in the works.



Close Up View of Link Switch and Liquid Fuse Panel.

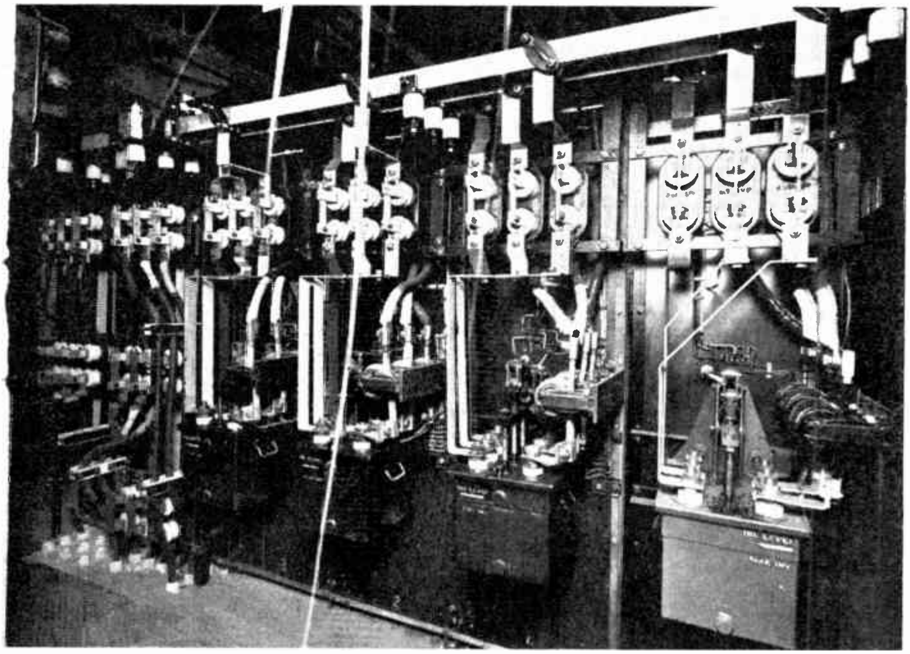
Distributing Panels for Outgoing Feeders.

From the feeder panels on the power switchboard cables are run to four banks of ironclad switch fuse panels of the unit type. Two of these are by M and C Switchgear, Ltd. and two by Johnson and Phillips.



A Johnson and Phillips Six-panel Sheet Steel Flat Back Type Switchboard.

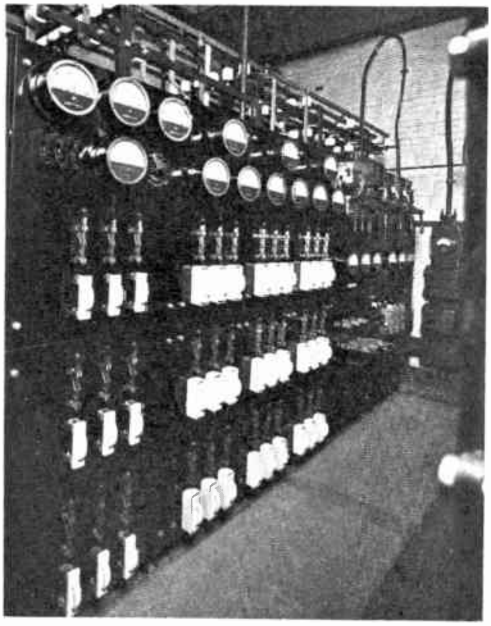
This is designed for operation on a 400-volt, 3-phase, 50-cycle system, arranged to control incoming supplies from four 250 kVA. transformers and 400-ampere outgoing feeders. Incoming feeders controlled by means of 600-ampere triple pole automatic oil circuit breakers and outgoing feeders by means of air break isolating switches.



BACK VIEW OF JOHNSON & PHILLIPS SIX-PANEL ENAMELLED SLATE FLAT BACK TYPE SWITCHBOARD. Arranged to control incoming supplies from 200 kVA. and 100 kVA. transformers and twelve 100-ampere heating and lighting circuits. Incoming supplies controlled by means of air break automatic circuit breakers and outgoing feeders by means of air-break knife switches and fuses.

How the Feeder Cables are Bonded.

Each bank is subdivided into separate units all connected through a busbar chamber running the length of the complete panel. The feeders from the separate units are taken from the top of the unit and in nearly every case are 3 core 19/.083 V.I.R. steel armoured jute covered cables. The glands used for bonding the armouring to the trifurcating box at the top of the units is clearly shown in the photograph.



FRONT VIEW OF JOHNSON & PHILLIPS SIX-PANEL ENAMELLED SLATE FLAT BACK TYPE SWITCHBOARD.

Load Consumed.

The load consumed in the works has increased year by year since the first motor was installed in 1921, when the total units consumed was 55,000. The curve shows the gradual increase in the demand due to the expansion of the works, and it is estimated that for the year ending 31st December, 1932, the consumption will have exceeded 950,000 units.

Average Power Factor, .87—Although the of 3 ph. comm. A.C. motors which are installed in the press room, for driving the larger magazine rotary presses.

HERE WE SEE THE BANK OF IRONCLAD UNIT TYPE SWITCH PANELS BY M & C SWITCHGEAR, LTD. ON THE RIGHT IS A CLOSE UP VIEW OF GLAND, SHOWING METHOD OF BONDING WIRE ARMOURING

THE MACHINE ROOM.

Press Room Rotaries.

The Press Room naturally demands the highest load and it is estimated that 80 per cent. of the works load is taken by the motors driving the presses. There are altogether 32 magazine rotary motors installed throughout the works total about 2,000 h.p., numbering approximately in all 250 and ranging from 80 h.p. to ¼ h.p., the average power factor is .87, as verified by figures supplied by the supply company.

—And the Explanation.

This exceptionally good power factor is no doubt due to the number

General View of Composing Room.
Showing lighting by 130—100-watt gas-filled Mazda lamps in Benjamin R.L.M. reflectors.

presses, nearly all driven by double motor A.C. equipments, 13 being of B.T.H. manufacture, four by Witton James, two by the Fuller Electrical Company, all of which are fully automatic.

Pioneer Work in 1921 and 1922.

There are also four J. H. Holmes semi-automatic single motor equipments for the slower presses. These were the first alternating current motors to be installed at the works in 1921. As a matter of fact, it may be claimed that these latter must have been almost the first variable speed hand-operated A.C. 3-phase slip-ring motors which had ever been installed for driving printing presses. At any rate, the two 3-phase variable speed A.C. commutator motors (shunt characteristics) supplied by the Swedish General Electric Co. in 1922 were certainly the first of their kind installed in any printing house in this country. All these motors are still running and giving excellent service, besides having been trouble-free since they were first put down.

"THE RADIO TIMES" PRESSES.

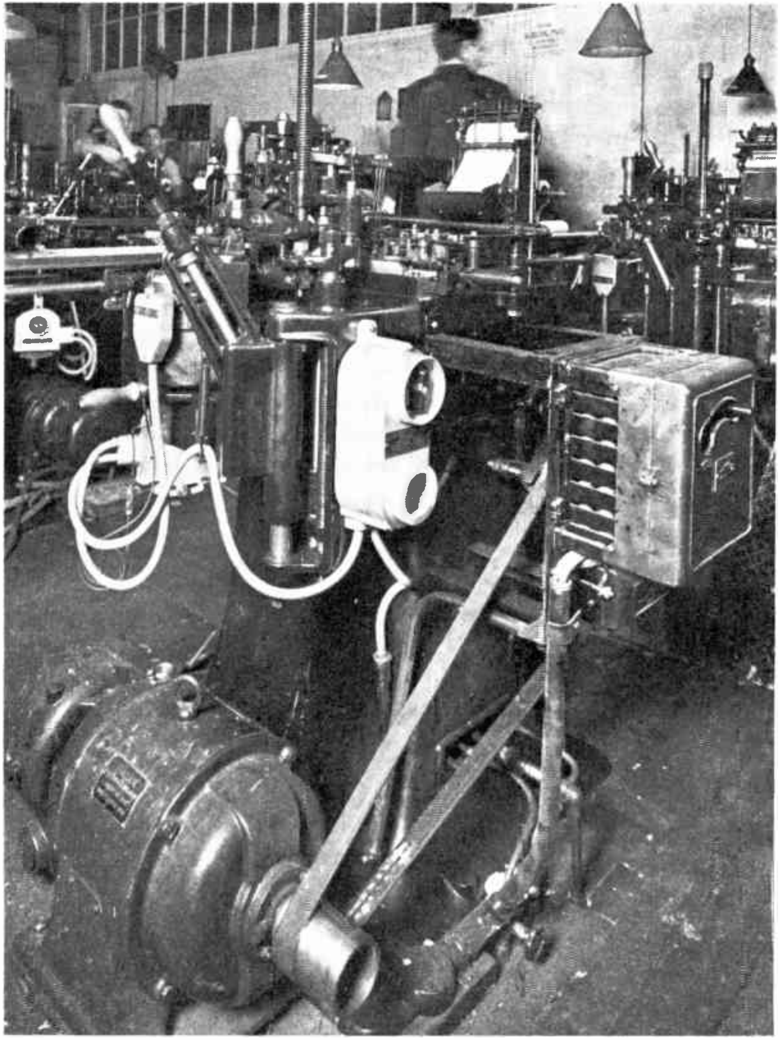
The most interesting and perhaps most up-to-date equipments are those driving the large magazine four-roll presses printing *The Radio Times*, and a general description of these units here may be of interest.

The Driving Units.

The driving units for the magazine rotary presses consist of main motor, barring motor, chain sprocket for drive to the press shaft, and worm reduction gear for the barring motor with a centrifugal ratchet type coupling and a solenoid brake. All the above parts are carried on a cast iron baseplate provided with slide rails for chain tension adjustment. The unit is erected in a pit at the side of the press, fitted with covers at floor level to allow the operators free access to all parts of the press.

Ratchet Coupling between Main Motor and Barring Motor.

The ratchet coupling allows the main



THE ELECTRO-FUNDITOR METAL POT HEATER.
All the casting and composing machines at the Newnes and Pearson Printing Works are equipped with this modern heating appliance. A Thermostat control maintains a constant temperature in the pot.

motor to overrun the barring motor and so automatically disengage the latter when the main motor takes up the drive.

All the mechanical parts of these units are supplied by Messrs. David Brown and Sons.

The barring motor is a B.T.H. double squirrel cage machine, rated to give ample starting torque under the worst operating conditions.

Characteristics of Main Motor.

The main motor is a B.T.H. A.C. shunt type commutator motor with a 4 to 1 speed range obtained by means of motor-operated brush-gear. This type of machine gives an infinite number of speed points over the working range and consequently gives extremely smooth acceleration and retardation. Both of these features are of great importance in printing press operation.

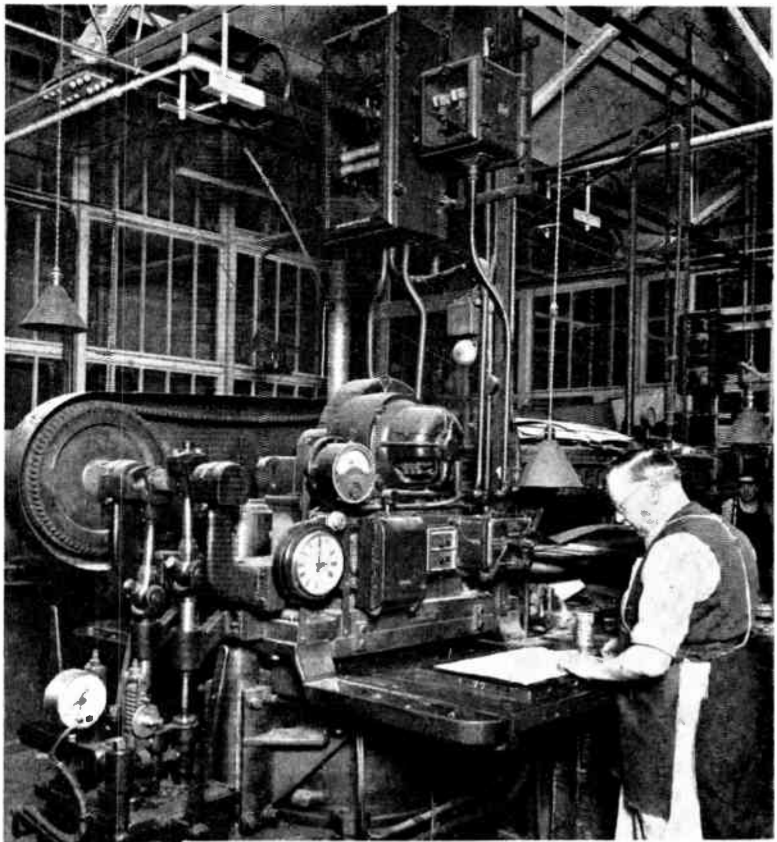
The driving unit for a single press has a continuously rated main motor of 55/14h.p. 870/220 r.p.m. and an half - hour rated barring motor of 6 h.p., 950 r.p.m., the worm gear ratio being 950/21.7 r.p.m.

Arrangement for Running Two Presses Simultaneously or as Separate Units.

In many cases at these works two presses are arranged so that they can be operated simultaneously to produce one publication and in these instances six of the presses are equipped with a driving unit consisting of an 80/20 h.p. main motor and 8 ½-h.p. barring motor. The two presses can then be coupled mechanically and driven by the 80 h.p. unit.

Push - Button Control.

The B. T. H. control gear is of the fully automatic contactor type controlled by push buttons mounted at various points on the press frame. The contactor panel carries a motor - operated master drum switch which operates the contactors in the correct sequence and with the appropriate time delays where necessary. It also carries a hand reversing switch for the barring motor for use in exceptional circumstances, such as when the press has to be reversed by hand.



THE GIGANT MOULDING PRESS.

Three factors are of prime importance in operating this press :—

(*a*) The working pressure must be "just right" (in this case, 1,750 lb. sq. in.).

(*b*) The heat applied to the mould must be accurately controlled.

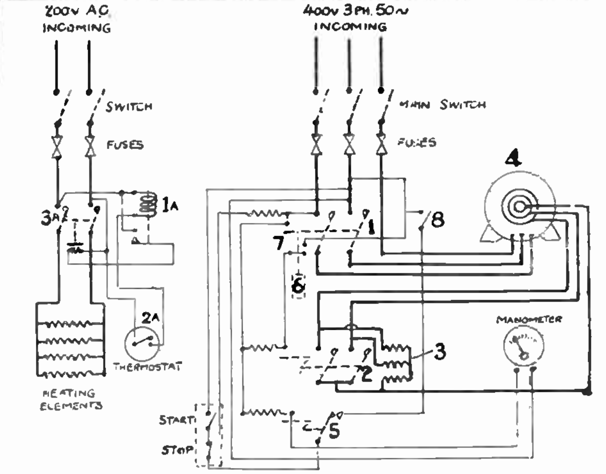
(*c*) The mould must be kept under pressure for a definite time—neither more nor less.

In this plant all these factors are controlled electrically.

(*a*) The manometer needle closes a contact and stops the motor when the correct pressure is reached.

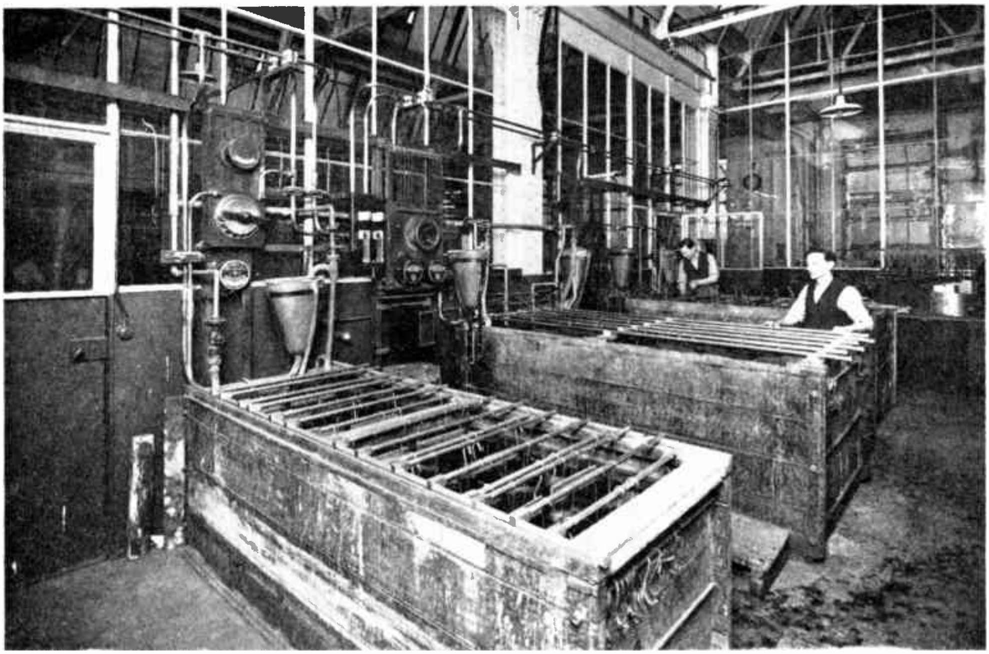
(*b*) A Thermostat controls the heat applied to the mould to within 3° F.

(*c*) The minute finger of an electric clock closes a contact and rings a bell as soon as the correct number of minutes have elapsed.



1A - RELAY WORKING FROM THERMOSTAT
2A - THERMOSTAT
3A - MAIN HEATING CONTACTOR

1 — STATOR CONTACTOR
2 — SLIP RING SHORTING CONTACTOR
3 — ROTOR EXT. RESISTANCE
4 — 3 PH. 400 V 50~ MOTOR
5 — PRESSURE GAUGE CONTACTOR
6 — RETARDING DASHPOT FOR INTERLOCK 7
8 — LOCKING INTERLOCK FOR STATOR CONTACTOR



HERE ARE SHOWN THE THREE CANNING VATS USED IN THE NICKELLING ROOM.
The solution is *electrically heated* and is agitated by compressed air whilst in operation. It is found that this nearly doubles the speed of working and gives a better deposit.

Two main push-button stations are provided for each press giving "inch," "raise," "lower," "stop" and "on and off" control. Also eight subsidiary stations are supplied labelled "safe" and "run" to safeguard the operators when working at remote positions on the press.

In those cases where an 80 h.p. unit has to drive two presses coupled together a multipole change-over control switch is provided to enable the presses to be controlled, if necessary, from those push-buttons which normally control the 55 h.p. unit.

Chain Drive Preferred.

Morse rocker joint chain drives are used on all equipments, as these have been found eminently suitable for the exacting work they have to perform owing to the continual inching, starting and stopping of the presses.

An interesting hoist block (Herbert Morris, Limited) is shown on page 220, the feature of which is the maximum amount of head room obtained for lifting. It will be seen from the picture that a special trolley framework is constructed, with the motor and rope drum mounted on one end and the lifting hook on the other.

The Flat Bed Presses.

In addition to the rotary presses there are installed a number of flat bed presses.

These are all driven by semi-automatic 3-phase A.C. motor equipments. Motors were by J. H. Holmes and Fuller Electrical and Manufacturing Company, and the control gear by Igranic Electric Company.

An Important Innovation.—The Photo-Electric Inset Registering Device.

An electrically operated insetter mechanism is now being worked successfully in these works.

The Purpose of the Photo-electric Control.

The purpose of the photo-electric control is to maintain running register between a pre-printed web and the printed matter on the main press.

DESCRIPTION OF THE PHOTO-ELECTRIC INSETTING DEVICE.

A description of this inset registering device, which has been developed by the British Thomson Houston Company in conjunction with Messrs. Newnes and Pearson Printing Company and Messrs. Hoe, Ltd., is here of interest. The first one was installed at these works and has given every satisfaction on actual production.

Duty of Inset Registering Device.

The function of the inset registering device is to feed a pre-printed web from a roll and to so control the feed that the printed matter shall always occupy the same position relative to the collating or folding cylinder within predetermined limits, in the present case plus or minus $\frac{1}{8}$ in.

Principle of Operation.

The apparatus consists of the following essential parts :—

1. Inset feeding device.
2. Photo-electric apparatus (built into feeding device).
3. Contact maker.
4. Control pillar.

The Feeding Device.

The feeding device consists essentially of a pair of rolls gripping the web, and driven from the existing cover printing section of the press. These rolls draw the web off the reel, and are driven through a variable speed gear. The feeding device also includes a compensating roll moving in a loop of paper, by means of which the web may be advanced or drawn back.

The Photo Cell.

The photo-electric cell device consists of a lamp arranged to throw a narrow beam of light through the web, this light impinging on a photo-electric cell. *Special marks are printed on the web*, bearing a definite relation to the normal printed matter, and the photo-electric cell is so connected through amplifiers and transformers that a momentary voltage impulse is produced on the output terminals every time a rapid variation occurs in the light received by the photo cell.

The Contact Maker.

The contact maker is driven through gearing from the collating cylinder so that it makes exactly one revolution for every copy delivered. It is provided with two contact making arrangements displaced from each other so that over a short part of the revolution neither contact is made.

Just prior to this, the "too fast" contact is made, and just after it the "too slow" contact is made.

These contacts are connected in circuit with the output terminals of the photo-electric device, and also with the apparatus controlling the correcting pilot motor, which apparatus is housed in the control pillar. If the impulse due to the passage of the mark or hole on the web past the photo cell occurs when both contacts are open, the correcting pilot motor is not started.

If the impulse occurs whilst the "too fast" contact is closed, the correcting pilot motor is started in a direction to retard the web.

If the impulse occurs when the "too slow" contact is closed, the correcting pilot motor is started in a direction to advance the web.

The Correcting Motor.

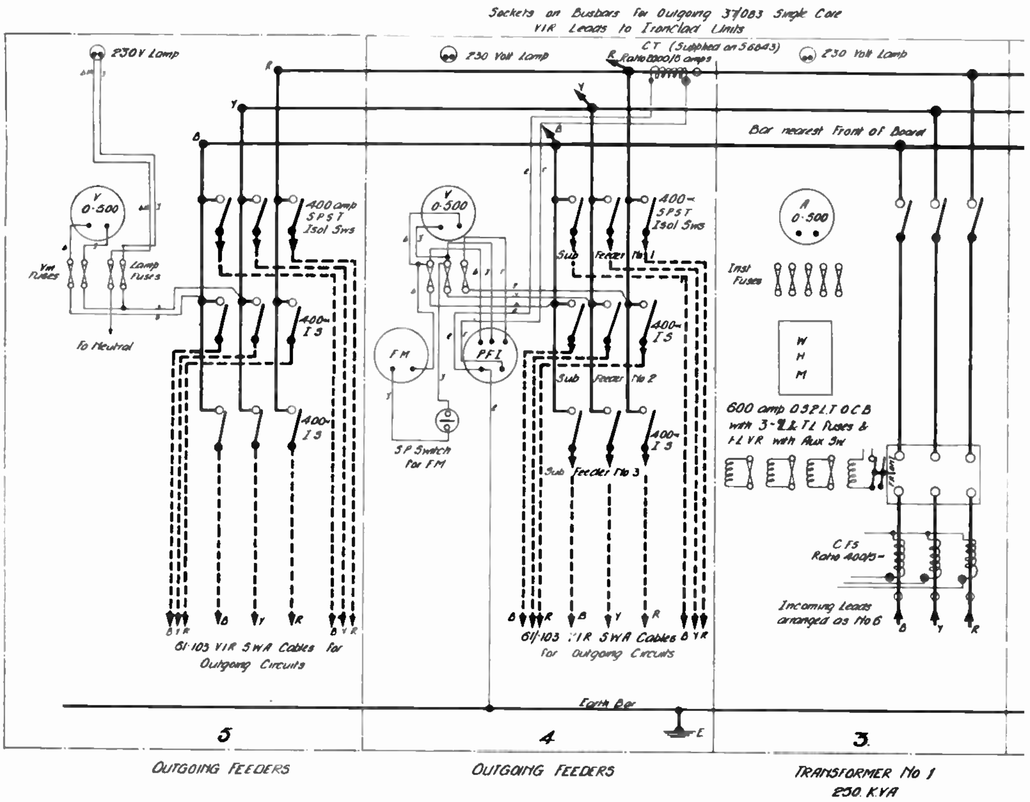
The correcting pilot motor performs two correcting functions simultaneously :—

(*a*) It makes a slight adjustment to the speed of the feeding roll by adjusting the variable speed gear, through which the latter is driven ; and

(*b*) It adjusts the position of the compensating roll. If the web is running too fast the feeding roll is slowed down and the compensating roll is moved in a direction to draw the web back, and vice versa.

Each impulse controlling the starting of the correcting pilot motor is momentary, but the pilot motor runs for a definite predetermined number of revolutions, this being determined by a cut-off switch driven from the pilot motor itself.

In order to avoid operation of the



CIRCUIT DIAGRA

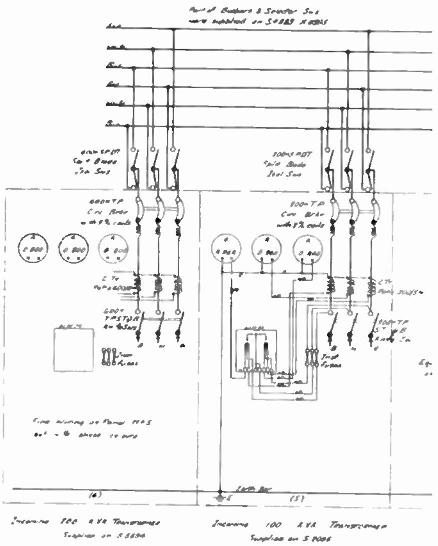
Johnson & Phillips six-panel sheet steel fl

correcting device by printed matter other than the lines specially printed for the purpose, a blank space is left on the pre-printed web immediately before and after these lines, and the contact maker is so arranged that contact is only made for a short part of the revolution corresponding to this blank space.

The Feed to the Folder.

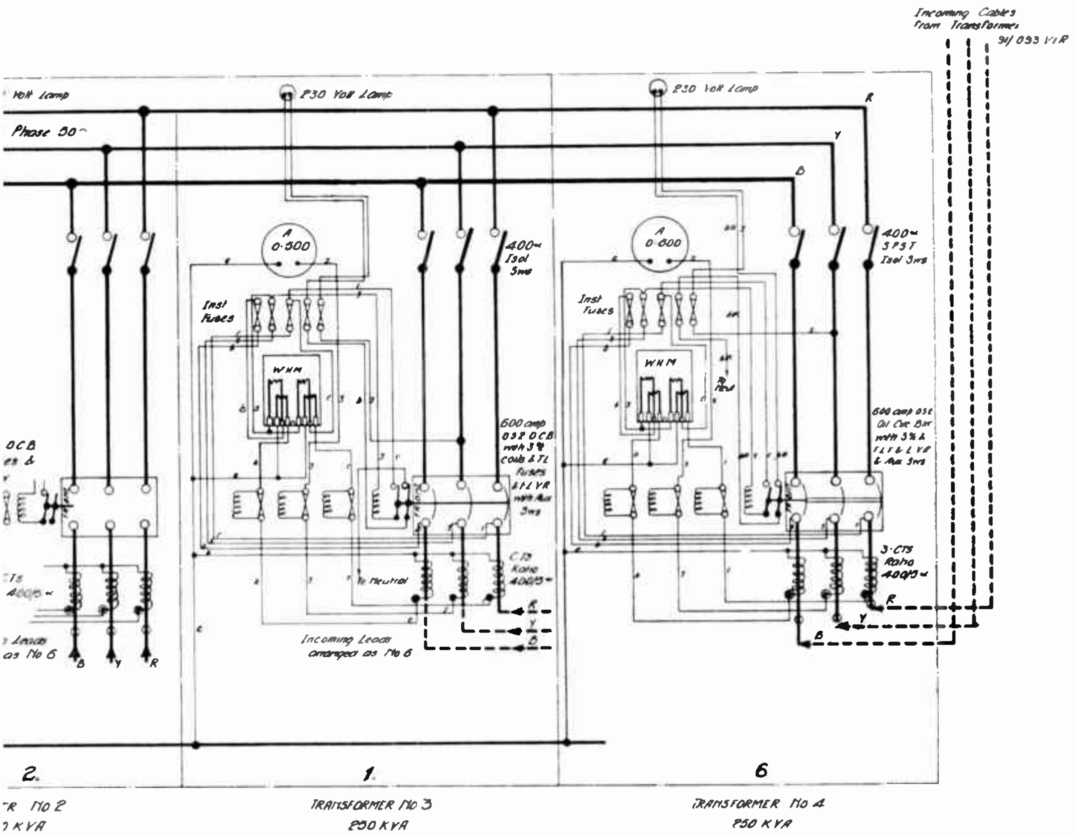
The web, on leaving the feeding device, is fed into the folder by existing drawing rolls geared to the folder, as at present. These drawing rolls maintain a tension on the web because their peripheral speed is slightly higher than the web speed. It should be borne in mind that when feeding pre-printed web which may have stretched slightly the mean speed of the pre-printed web may be slightly greater than would be the speed of a web printed on the press.

In addition to this, the intermittent

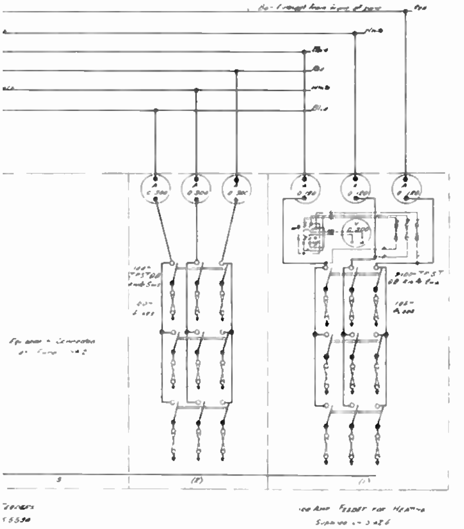


CIRCUIT DIAGRAM

Johnson & Phillips six-panel enamelled slat



:R SWITCHBOARD.
switchboard, 400 volts, 3 phase, 50 cycle.



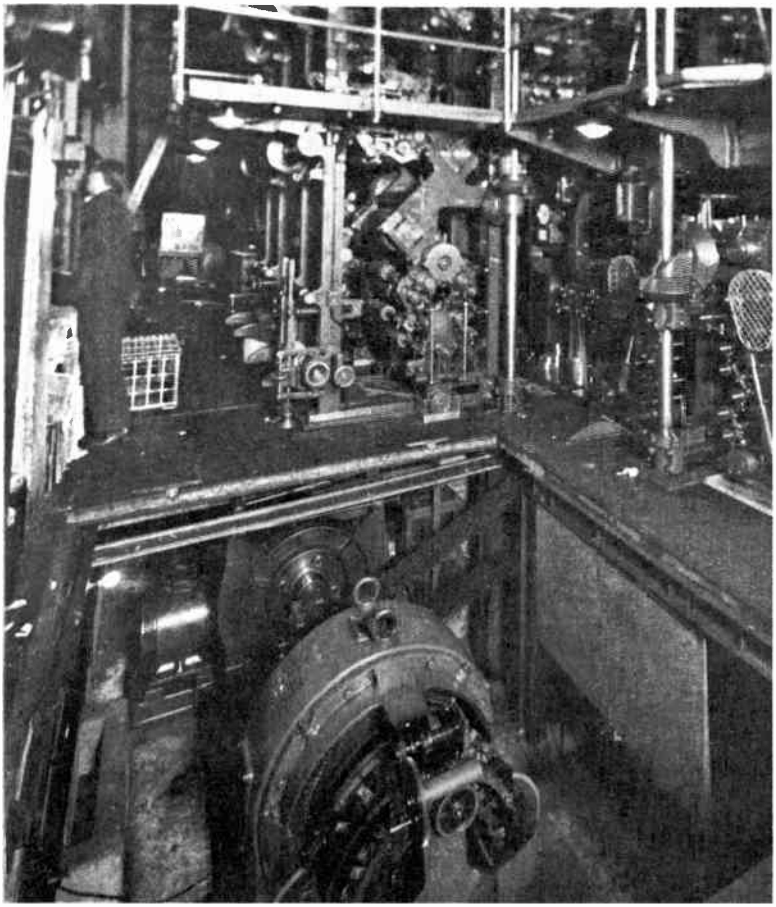
ING SWITCHBOARD.
ype switchboard, 200 volts, 3 phase, 50 cycles.

movement of the correcting device will produce periodically momentary increases of the speed of the web of the order of 0.1 per cent. above the mean speed. It is necessary that the peripheral speed of the drawing roll should be sufficiently high to maintain the tension on the web under these conditions.

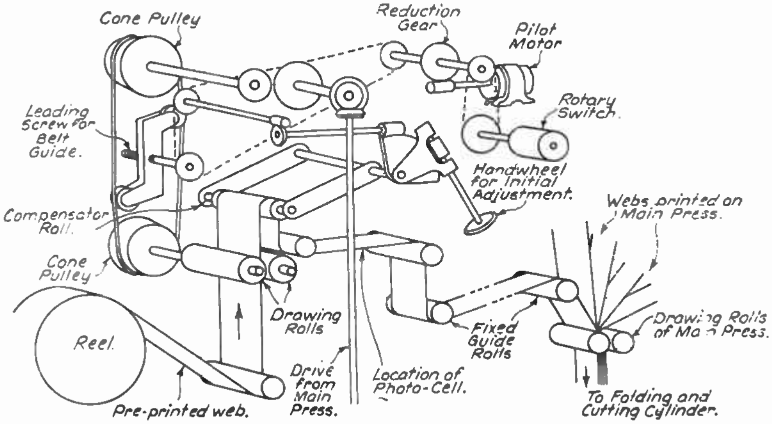
Mechanical Details.

The essential moving parts of the feeding device are shown in the sketch which is diagrammatic only, but serves to indicate gear ratios and direction of rotation.

It will be seen that the feeding rolls are driven through a variable speed gear of the belt and cone pulley type, driven through a pair of increasing spur gears and vertical shaft and mitre gears from the reel-up roll shaft on the cover section of the press. The gear ratios and roll diameter are such that with the belt in



VIEW OF THE MAIN DRIVE TO ONE OF THE HOE MAGAZINE PRESSES.
Note the barring motor on the left for slow running and also the small pilot motor which operates the brush gear for speed control.



DIAGRAMMATIC ARRANGEMENT OF MECHANICAL PARTS OF THE INSETTER.

its "mid" position the web will be fed through the feeding rolls at the same speed as it would be fed from the cover cylinder.

The cone pulleys allow of an increase or decrease of $2\frac{1}{2}$ per cent. in the feeding roll speed from this nominal speed.

How the Belt is Moved Along the Cone Pulleys.

The belt can be moved along the cone pulleys by means of two flanged guide pulleys, which are traversed by means of a screw rotated through chain gearing by the pilot motor.

How the Compensating Roller is Operated.

The same chain through a worm gear and worm quadrant moves the radius arms carrying the compensating roller. The possible movement of the compensating roller is therefore tied up directly with the movement of the belt guide, and this movement is limited by suit-

Six Electrically Driven Greenbat Trucks Enable the Huge Output to be Handled Quickly and Efficiently.

Each truck has a battery of 12 Ironclad Exide cells of 129 amp. hrs. capacity supplying current to Greenwood and Batley totally enclosed traction motor.

able stops; should either stop be reached due to some accidental condition, damage is prevented by a slipping clutch interposed between the pilot motor and the chain gear.

Self-stopping Action of Pilot Motor.

The pilot motor also drives a cut-off switch, which is arranged to stop the motor after one revolution of the switch.

How the Web is Adjusted for Register Before Starting.

In order to permit of rapid hand adjustment of the register being made when the web is first fed in, since there is nothing to indicate the correct instant at which it should be fed between the feeding rolls, an arrangement is provided whereby he automatic compensator roll referred to above can also be moved by means of a hand-wheel. The movement obtained in this way is limited by stops, so that when the hand adjustment has been made to its full extent the roll still has sufficient play for the full amount of automatic adjustment. Sufficient hand adjustment is provided to extend over considerably more than the full length of one cover.

It will be understood that the effect of the automatic inset control is to maintain a constant relation (within limits) between the position of the printed matter and the position of the collating cylinder; what this relation is, however, must depend on the length of web between the photoelectric device and the collating cylinder, and this length can be adjusted by means of the existing compensator controlled by a handwheel. By means of this second compensator, therefore, it is possible to arrange that the printed mark shall appear on the fold, or on any other portion of the sheet desired.

Electrical Arrangements.

The equipment is arranged for both a 400 volt, 3-phase, 50-cycle A.C. supply and a 400/200 volt, 3-wire D.C. supply. The A.C. supply serves for the pilot motor and for the valve and thyratron heaters whilst the D.C. supply serves for the photo cell valve and thyratron anode circuits. Both supplies are brought to the control pillar, which should be located as near as convenient to the inset feeding device.

The pillar houses, in addition to the control gear for the pilot motor, have a contactor controlling the A.C. input, and another contactor controlling the D.C. input.

It is desirable that the valve and thyratron cathodes should have time to heat up before the device is brought into operation, and the contactor controlling the A.C. input will therefore be interlocked with the existing control panel of the press, so that it will close as soon as either the barring motor or the main motor is started up and will remain closed until the "off" push-button referred to below is pressed.

The D.C. input contactor is controlled entirely from an "on" and "off" push-button station located on or near the inset feeding device. This push-button station will be so wired that pressing the "on" button brings the automatic registering device into operation, pressing the "off" button takes the device out of operation, and at the same time if the press is at a standstill cuts off the A.C. supply to the registering equipment.

THE COMPOSING ROOM.

There are two installations in the composing room which are of interest, viz., the lighting and the electric driving of the monotype casting machins and the electrical heating of metal pots on same.

Lighting—Spacing of Lamps.

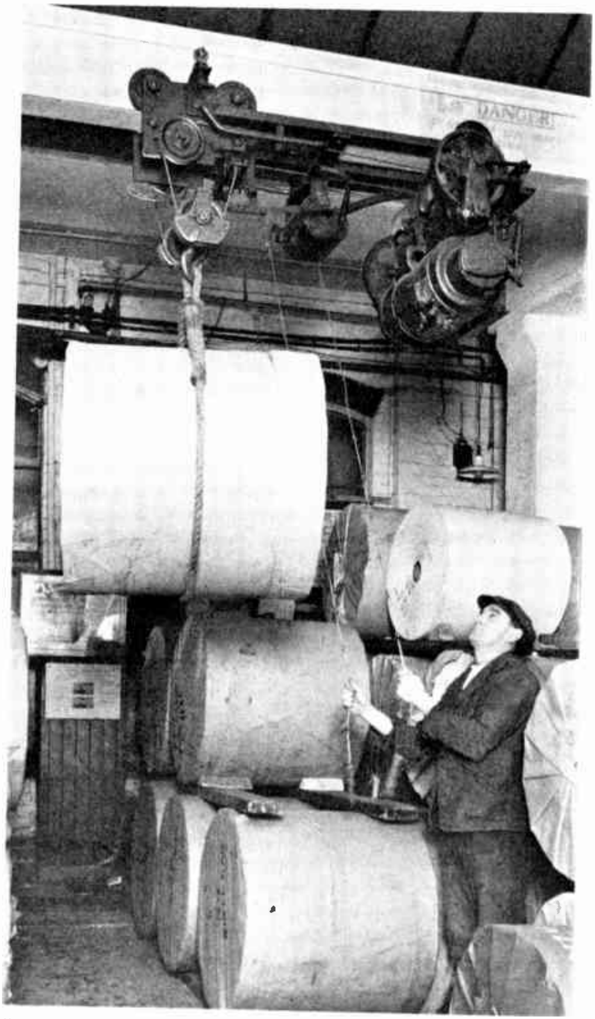
The lighting in the main composing room is carried out by means of Benjamin R.L.M. reflectors with 100-watt gas-filled lamps. The arrangement is clearly shown in the photograph on page 211. The lamps are spaced 5 ft. apart and 8 ft. from the ground, giving an intensity of about 10/12 foot candles at the working plane.

Monotype Casting Machines—Electrically Driven and Heated.

The monotype casting machines are all driven by their own individual motors. The photograph shows a Fuller ½ h.p. 3-phase 50-cycle 90/580 r.p.m. slip ring motor driving one of these machines, the variable speeds being obtained by hand operated rheostat fixed on frame work on side of machine. Similar motors supplied by Messrs. Witton James are also installed on a number of the casting machines.

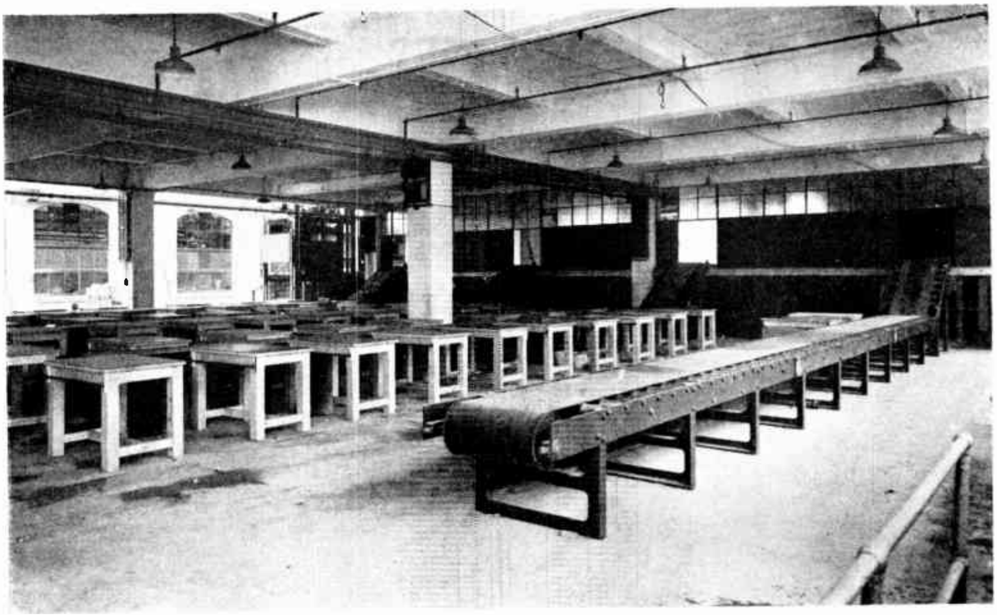
Funditor Fitted on Monotype and Linotype Machines.

The Electro Funditor fitted to the monotype and linotype machines is now constructed in the London works of



THIS SHOWS THE MORRIS ELECTRIC HOIST-BLOCK SPECIALLY DESIGNED TO GIVE A MAXIMUM HEIGHT OF LIFT IN MINIMUM HEAD-ROOM.

The controller is chain-operated. The motor is 3-phase, supplied from overhead trolley wires one of which can be seen in the picture.



ELECTRICALLY DRIVEN BELT CONVEYORS.
Four of these are in use, in the new building. They were supplied by S.A.P., Ltd.

Messrs. Funditor, Limited, of Mitre House, Fleet Street, E.C. The heating elements are immersed directly into the metal and by means of the specially designed regulating box, automatic control of the temperature of the metal, within the limits of 3°, can be obtained. The regulating box consists mainly of a mercury thermostat connected to a hollow spiral, which will expand and contract through the influence of a variation in temperature of metal. The spiral acts on a rod which is connected with a lever controlling a tilting mercury switch.

THE FOUNDRY.

Nickel Room.

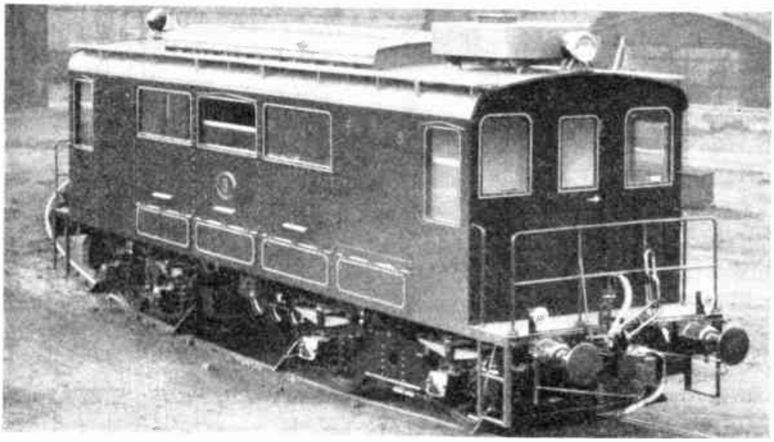
The arrangement of copper bars from the plating sets to the nickelling baths is clearly shown in the photograph on page 214. They are of .78 sq. in. section round copper bars. Two of the baths receive their current from a Canning 6-volt 750-amp. motor generator set, self-excited, running at 950 r.p.m., and the third bath from a Holmes 6-volt 250-amp. set, separately excited (shown in photograph). Considerably increased production in the depositing process is obtained by a motor-driven agitator plant.

"Gigant" Moulding and Drying Press.

The "Gigant" automatic moulding and drying press, now manufactured in this country by S.A.P., Limited, of Fleet Street, is a self-contained unit complete with motor equipment and electrical heating. The whole of the electrical equipment is either mounted directly on the press or in close proximity to it, so that everything is under the eye of the operator. The motor for operating the self-contained oil pump, on the hydraulic principle, is a 4 b.h.p. 400-volt 3-phase 50-cycle A.C. slip-ring motor by Witton James running at 1,420 r.p.m. and is started and stopped by push button. The pressure required on the formes is set on the manometer—on this particular press up to 1750 lb./in.^{2}—and is maintained at the set pressure until the motor is stopped. The heating of the table is also done electrically and can be set to any desired temperature from 250° to 350° F., and is thermostatically controlled to maintain the set temperature within the limits of 2° to 3°.

A DIESEL-ELECTRIC SHUNTING LOCOMOTIVE

WE have just witnessed a demonstration of one of the diesel-electric locomotives in the Rugby works of the British Thomson-Houston Company. The locomotive is one of a number which has been made for use in the Ford Motor Works at Dagenham.



THE B.T.H. 44-TON DIESEL-ELECTRIC LOCOMOTIVE READY FOR DUTY.

Not a Substitute for Main Line Electrification.

These diesel-electric locomotives are designed to have just the right characteristics for their work, and from an electrical engineering point of view they are extremely interesting. They are not, of course, intended as a substitute for main line electrification where the requirements are entirely different from those of shunting operations.

The Engine.

The power unit consists of a six-cylinder, four-stroke, airless injection "Allen" diesel engine, rated 150 h.p., at 550 r.p.m. continuously, and capable of giving 10 per cent. overload for two hours or 40 per cent. momentarily.

The Main Generator and Motors.

This is directly coupled to a 95 kilowat generator which is mounted on the same bedplate. The generator is compound-wound with separately excited shunt and differential series windings and compoles, and is designed to have a drooping characteristic. There are four traction motors, two on each bogie. Two motors are connected permanently in series.

Control.

A special patented device is provided which enables any of five different settings to be given to the governor gear so that the engine will run at either 150, 250, 350, 450, or 550 r.p.m. The motors can be run either all in series or in series-parallel. Provision is also made for running the motors with a weak field. The sequence of operations follows:—

(1)	Engine Governor Setting	150 r.p.m.	Motors in Series.
(2)	,, ,, ,,	250 r.p.m.	,, ,,
(3)	,, ,, ,,	350 r.p.m.	,, ,,
(4)	,, ,, ,,	450 r.p.m.	,, ,,
(5)	,, ,, ,,	550 r.p.m.	,, ,,
(6)	,, ,, ,,	550 r.p.m.	Motors in Parallel Full Field.
(7)	,, ,, ,,	550 r.p.m.	Motors in Parallel Weak Field.

The master controller has a "dead man's handle" which cuts off the power and applies the brakes if released in a running position.

Performance.

The equipment was started up from cold in less than one minute.

The most noticeable feature about the performance was the wonderfully smooth acceleration and extreme ease of handling.

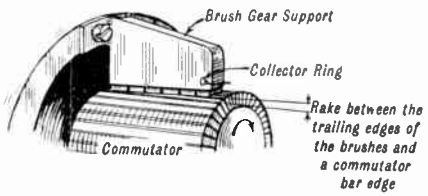
The fuel consumption ranges from $1\frac{1}{2}/1\frac{3}{4}$ gallons of oil per hour with a performance of 250/300 ton miles per gallon.

BRUSH TROUBLES AND CURES

By F. C. ORCHARD, A.M.I.E.E.

In this article Mr. F. C. Crchard deals with some of the causes and cures of sparking at the working edges of brushes

SPARKING at the working edges of brushes is a trouble met with sooner or later by every user or operator of rotating electrical machinery, and the causes are sometimes difficult to diagnose. The cure after accurate diagnosis, however, is very often obvious and easily put into effect.



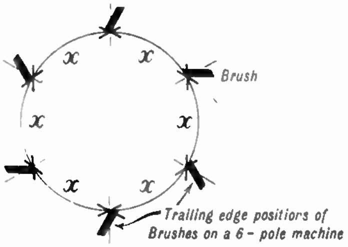
FAULTY BRUSH ALIGNMENT TEST.

For easy reference the main causes of brush sparking and the cures will be divided into two classes, those due to mechanical and those due to electrical effects.

MECHANICAL CAUSES.

1. Faulty Brush Alignment.

Sparking will be observed on those brushes situated farthest forward of other brushes in the direction of the armature rotation. To check up the alignment, bar the armature round until the trailing or leaving edges of the brushes coincide with the edges of a commutator segment. If there is a rake, i.e., if the brushes and the commutator bar edge do not coincide right across the commutator, then adjust the brush arm or carrier until coincidence is obtained. A word of warning however, is necessary in making this adjustment; do not alter the inter-spacing between adjacent brush arms when realigning the faulty arm.



Interspaces "X" should all be exactly equal.

INCORRECT BRUSH SPACING TEST.

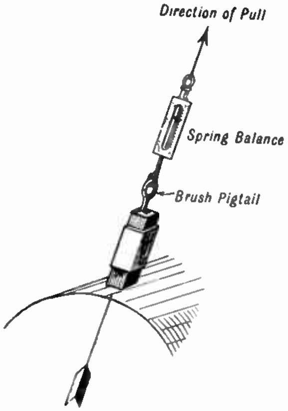
2. Incorrect Brush Spacing.

The symptom is the same as for fault No. 1 and in order to check up the spacing between the brush arms all round the commutator, wrap a piece of cartridge paper tightly round the commutator and mark very carefully indeed the leaving edges of each set of brushes. The marking must be done as accurately as possible for an error in this check of even 1/32 in. may mean overlooking the true cause of a sparking trouble. Remove the paper and check up by measurement the distances between the marks. These should all be regular.

3. Incorrect Brush Pressure.

It is essential that the pressure exerted by the brush spring should be of the correct value for the size and grade of brush used as well as for the purpose of such use. To test for correctness of pressure use a spring balance and make a pull on the pigtail absolutely vertical to the plane of the working face of the brush. This is important if accurate readings are to be made.

Normal pressures for carbon or graphitic brushes are 1½ lb. per square inch of working contact area of the brush on the commutator or slip ring for turbo-alternators; 2½ lb. per square inch for traction rotary converters or heavy rolling mill motors, i.e., plant subject to sudden heavy over-loads; motor car starters about 9 lb. per square inch, and motor car generators 6 lb. per square inch. For brushes on slip rings about 3 lb. per square inch is a suitable pressure but if metallic brushes are used then a pressure up to about 4½ lb. per square inch may give better results. The symptoms of incorrect brush pressure are glowing of brushes, discoloured pigtails due to overheating, burning of brushes and blackening of the commutator.



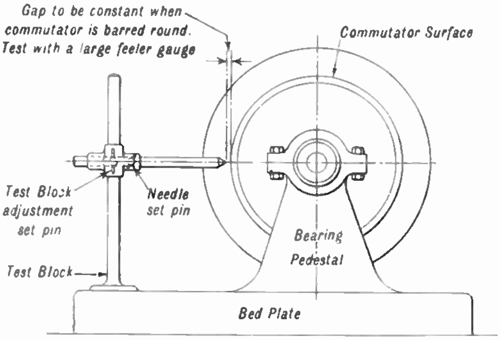
INCORRECT BRUSH PRESSURE TEST.

4. Chattering.

Brush chatter may be produced if the brush arms are not rigidly supported or if excessive clearance exists between brush holder and brush. The cure is obvious.

5. Brush Clearance.

When the clearance is excessive vibration or chatter will be set up and if armature oscillating gear is fitted the chatter will be in two directions and have a marked tendency to produce flats on the commutator in addition to producing very bad sparking. Conversely lack of sufficient clearance will cause the brushes to bind in the holders so that as wear takes place the spring tension is not capable of keeping the contact pressure at the desired value. Accumulation of dust and dirt will prove to be the most likely cause of this last trouble. The correct clearances, however, which should not be exceeded are 0.007 in. in the circumferential direction or 0.009 in. in the axial direction at any time.

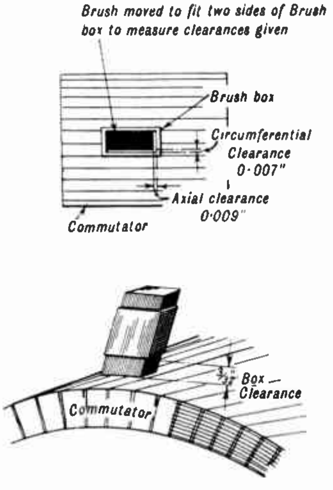


COMMUTATOR ECCENTRICITY TEST.

Furthermore, the distance between the bottom of the brush holder and the face of the commutator or slip ring should be adjusted to give a clearance of $\frac{3}{32}$ in.

6. Eccentric Commutators.

Sometimes a commutator becomes eccentric due to repeated heating up and cooling down under service conditions, producing a slacking off in the commutator bolt tension. High bars may be produced at the same time. When the machine speed is high the time for up and down motion of the brush in the holder may be such that the brush may actually leave the surface of the commutator and on the downward fall be struck a hard blow by the high bar during rotation. In other words the brush fails to follow the motion of the surface of the commutator and brush bouncing will result with bad sparking and the production of flats if the trouble is not cured at once.



BRUSH CLEARANCES.

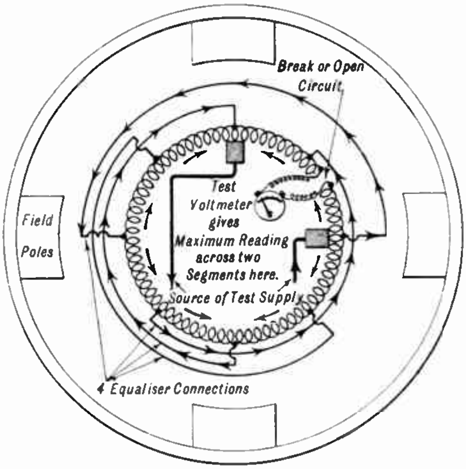
To check for eccentricity use a scriber fixed in such a way that the point is near to the surface of the commutator and then to bar the armature round carefully, noting whether the gap remains constant all round the commutator. The cure is to run the machine if possible on load for a sufficient length of time to get the commutator hot, then the machine should be shut down and the commutator bolts should be pulled up tight. The commutator must then be turned.

7. Commutator Segment Burring.

Burring will cause brush chatter and sparking so that it is a good practice after undercutting the mica insulation between segments to slightly bevel the edges of the bars.

8. High Bars.

These produce a distinct clattering noise as they strike the leading edges of the brushes and frequently the brushes are chipped in consequence of these blows. Any bars showing bright leading edges must be suspected. Apply cure as in 6 above.

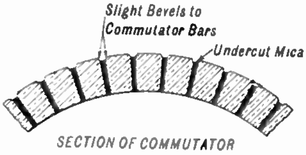


Testing for an Open Circuit in the Armature of a Lap Wound Machine Fitted with Equaliser Bar Connections. Test Current Flows in the Direction of the Arrows.

Note that if no equalisers are fitted, current may be circulated through the windings at diametrically opposite segments however many poles are used. For a four-pole wave winding with two circuits, but without equaliser connectors, circulate test current through segments one brush gear interspace distance apart. In this case, however, there will be two high voltage readings at diametrically opposite points of the commutator.

9. Low Bars.

This fault is invariably the result of bad works assembly and if the subsequent turning has not been properly carried out flats will be observed. Returning is the only safe cure.



Commutator Segment Burring.

10. Armature Balance.

Out of balance of the armature will cause a fluctuation of brush pressure and sparking. The cure for this is not always possible on site and is a matter to be taken up with the manufacturer.

11. Faulty Connections.

Where bad soldering of the joints between the bars and the windings are found, then flats will nearly always be found, too, on the affected bars. To cure the sparking remake the joints.

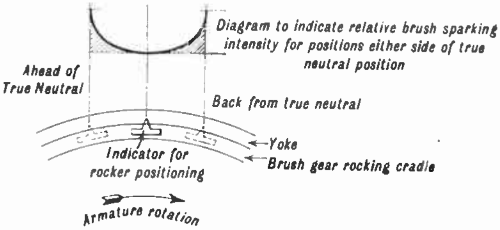
12. Air Gaps.

If the air gaps of the field poles or of the commutating poles are not arranged to give a good flux balance to the whole system of the machine, circulating currents will flow within the armature and will result in bad sparking. (See No. 16.) Brush curves should be taken and the thickness of shim packing adjusted to give a straight line potential curve at full load.

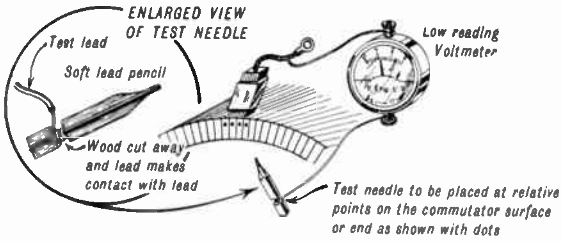
ELECTRICAL CAUSES.

13. Armature Open Circuit.

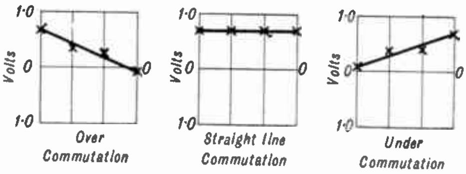
When an open circuit occurs exceedingly bad sparking will be experienced and often the sparking will develop into



Incorrect Neutral Position Test.



METHOD OF TESTING FOR TAKING BRUSH CURVES



TYPICAL BRUSH CURVES.

Air Gaps.

If the air gaps of the field poles or of the commutating poles are not arranged to give a good flux balance to the whole system of the machine, circulating currents will flow within the armature and will result in bad sparking.

severe flashing. The mica between the bars connected to the open circuited coil will be found to be badly burned. The failure of a joint connection between a bar and the coil will give the same effect. Also a partial failure which introduces a high resistance in the coil circuit will give similar results. Replacement of the faulty coil or remaking the faulty joint is the remedy. As a check against the visual location of the trouble arrange to pass a small amount of current at a very much reduced voltage through the armature while the machine is at rest and with a suitable sensitive voltmeter take pressure readings between consecutive bars around the commutator. An abnormally high reading indicates the locality of the faulty coil or joint.

14. Short-circuited Armature Coils.

Suspect these if a pulsating vibration is noticed in the machine and the comm. bars are found to be burned. Repeat test as for 13 above but in this case an abnormally low reading will indicate the seat of the trouble. A rough practical test may be obtained by running the machine with an excited field but off load and if a heavy soft piece of iron is held near to the armature and pulsations are felt in the test piece, then the worst may be feared. Shutting down the machine and feeling round the armature one may find a coil which is much hotter than the remainder. Coil replacement is required.

15. Incorrect Neutral Position.

If the machine has not been set with the brushes in the electrical neutral position sparking will be the result. By rocking the brushes backward then forward through the neutral position to some point ahead of neutral with a constant steady load on the machine a position will be found where sparking is a minimum. However, when convenient it is advisable to test for the true neutral position by the " kick " method or by running the machine excited but with brushes lifted and pressure difference readings taken across a two-bars distance at a place normally covered by a brush, while the brush gear is rocked. The neutral position is the one giving minimum potential difference.

16. Faulty Field Coils.

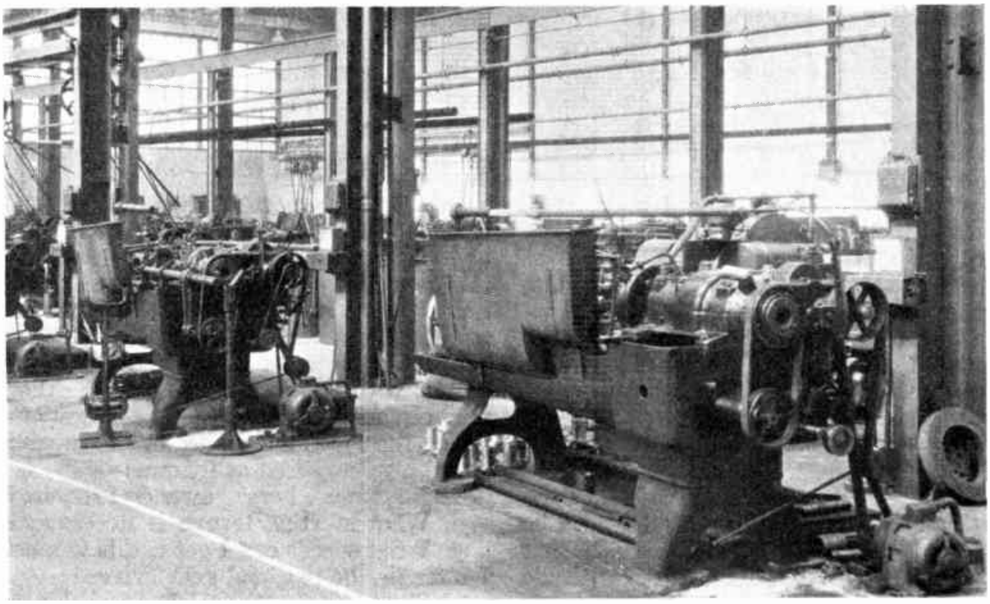
Whether the fault is due to faulty windings or faulty connections, an out of balance of flux distribution in the field system with consequent circulating currents in the armature will arise. If no equaliser connectors are fitted to the machine then these circulating currents will pass through the brushes and sparking will be observed on certain arms only. The volt drop across each field coil should be the same.

These causes and effects do not exhaust the subject for a book could quite easily be devoted to it, but sufficient information has been given to cover the more common cases met with by the average maintenance man in the works or substation.

THE CHANGEOVER PROBLEM IN ELECTRICALLY DRIVEN FACTORIES

By ROBERT RAWLINSON

The question of group versus individual drive is of great importance to the works engineer in the frequency change of a factory, and this important question is fully discussed in this series of articles



A MODERN INDIVIDUAL DRIVE MACHINE SHOP.

BEFORE the inception of the "Grid" with its standard frequency, there were many small individual stations supplying electrical power to factories, and these worked some on D.C. and some on A.C., while in the latter case there were many different frequencies, such as 25, 33⅓, 40, 50 or 83⅓ cycles, to mention only a few. The completion of the super power network will see the abolition of the non-standard systems and frequencies with the result that any factory or works which obtained its supply at anything but three-phase, 50 cycles, will be faced with the problem of changing over to the standard frequency.

The Changeover Problem.

Where the original supply was taken on the D.C. system, it will be necessary to replace every motor except, perhaps, the very smallest, which may be of the universal type. This changing of motors will apply in every case, unless the D.C. load is exceptionally heavy and unless there are a number of applications for which D.C. is absolutely essential. In these cases it may be most economical for the supply authority to install converting plant, but it may be taken that this will only apply in exceptional circumstances. The average factory will have to change over to the A.C. system in every case.

In those instances where the origina supply was taken on the A.C. system, but where the number of phases or the periodicity differed from the standard of three-phase, 50 cycles, it will be necessary to change the majority of the motors in some way. In certain cases, it may be possible to rewind or reconnect some machines so that they will operate with almost the same characteristics when connected on the new supply ; in other cases, the motors must be replaced ; and some few small motors will not require any attention at all.

The Attitude of the Supply Authorities.

The general attitude of the supply authorities has usually been extremely helpful. Since they are responsible for the cost of the changeover and have either to carry it out themselves or else remunerate their customer for the cost of the new or altered machines (being credited, of course, for any replaced motors or scrap), they have taken up the stand that a factory may reorganise its motor power to any reasonable extent providing the cost does not exceed that of a plain machine-for-machine replacement, or adjustment, or alteration of existing motors where this is possible. A couple of cases will make this clear.

A Typical Case.

Suppose that a factory already has 200 D.C. motors, all of which will have to be replaced, the cost of complete replacement being £2,000. According to the attitude of the supply authorities which has so far obtained, this factory may reorganise its plant and drives in any way it wishes, providing only that the cost to the supply authority does not exceed the £2,000, which would be the cost of a plain changeover. Any excess of cost over this figure must be borne by the factory itself, but no stipulation is made as to the number of new motors which are installed ; they may either exceed or be less than the original 200, as the reorganisation demands.

Another Example.

In the second case we may consider a factory which originally obtained its supply on the three-phase A.C. system, the periodicity being different from the standard 50 cycles. Suppose that in this case there are 20 motors which may be rewound or reconnected at a total cost of £400, and that 200 motors must be replaced, the cost of which would be, as before, £2,000. This factory also may revise and reorganise its motor power in any way it wishes so long as the supply authority is not called upon for more than the plain changeover cost as set down above, i.e., £2,400. Any reasonable number of new machines may be installed, but the factory must bear any excess of cost over the £2,400 already mentioned, and in some cases there is a stipulation that the power factor must not be appreciably lower after the changeover is completed.

Questions Which Arise.

In most cases, full advantage of the changeover is taken in order to reorganise and modernise the electrical drives of the factory, but before this can be done, consideration must be given to the different characteristics which the new 50-cycle motors will exhibit when compared with the machines which they are replacing. Some of the questions which the factory engineer has to answer may be summarised as follows :—

1. How many horse power do I require ?
2. What starting torque is necessary ?
3. What speeds can I get and how must I alter my belting and gear drives ?
4. Shall I regroup my driven machines, or would individual drive be better ?
5. Which of my existing A.C. machines can I alter ? Can my own maintenance electricians carry out the alterations, and how shall I work out the correct windings or reconnections so as to make the altered motors suitable for the new supply ?
6. Can I take advantage of the new types of motors and enclosures so as to gain improved reliability, better operation and easier maintenance ?
7. Will it pay me to install special power factor correction apparatus ?
8. How can I deal with the applications which must have a D.C. supply ?

The above queries are the main ones which should be carefully considered before commencing any alterations to the factory drives. Next month we shall deal fully with methods of determining the horse power required.

THERMAL OVERLOAD TRIPS FOR SMALL MOTORS

By G. W. Stubbins, B.Sc., A.M.I.E.E.

Till quite recent years the fusible cut-out was the only convenient available device for the protection of small motor circuits. Although the fuse is very suitable for lighting circuits, in which excessive currents rarely occur excepting through insulation failure, it has serious limitations when used for motor circuits, and particularly so when the motors are of the A.C. induction type.

Why Fuses are Unsuitable.

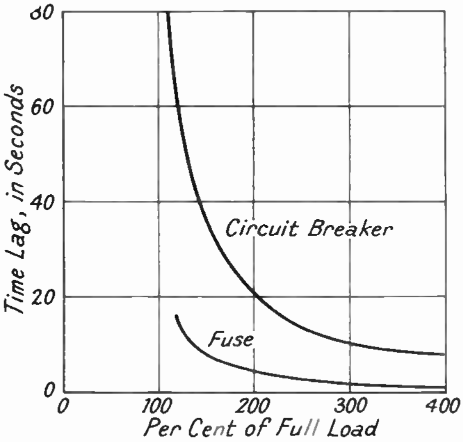
The unsuitability of the fuse in such a circuit arises from two circumstances. In the first place, it is possible for a current to flow in a motor circuit which, although not excessive to the degree of a short circuit current, is too high to be carried for any but a limited period. Secondly, transient currents which may be four or five times the full load value may be taken by the motor during starting conditions, the operation of the machine being quite normal. Although the action of a fuse in interrupting a circuit is not instantaneous, except the current have a very high value, the time lag in its operation is never very large. In other words, if with a fuse of certain size we pass a current which is very little in excess of that which it can just carry indefinitely, the action of the fuse will not be delayed for more than perhaps 20 seconds. If, therefore, the size of the fuse in a motor circuit is so graded as to be large enough to carry the heavy starting current the fuse will be too large to protect the motor in circumstances when currents representing moderate overloads are flowing.

The Small A.C. Induction Motor—Starting Conditions.

It will be useful briefly to recapitulate the nature of the conditions in which abnormal currents can flow in a motor circuit without there being any failure of the insulation. We have already referred to the high starting current required by small A.C. induction motors of the cage rotor type, as these motors are, almost invariably. The reason that a motor of this type requires a very high starting current in comparison with a direct current motor of similar rating is that, at the instant of starting, the current taken by the motor is of very low power factor.

Result of Low Power Factor.

The result, or we might almost say the meaning of the low power factor, is that the association of the motor current and voltage gives rise to a relatively feeble torque on the rotor. If the starting current of a cage rotor induction motor were limited by inserting resistance in the circuit, as is done with a D.C. motor, the starting torque would be so reduced that the motor might not start. A high starting current, of the order of three or four times the value of the full load current, is therefore almost essential with small A.C. induction motors.



Illustrating the Difference Between the Time Lags of a Fuse and a Thermal Overload Release.

"Single-phasing" of Three-phase Motor.

Moderately excessive currents in an A.C. motor circuit can, of course, be set up by overloads, as with a D.C. motor. There are, however, two circumstances, other than overloads, and peculiar to A.C. motors, which can give rise to excess currents. One of these circumstances arises from what is known as the single-phasing of three-phase motors. If one of the leads supplying a three-phase motor is opened, the motor will continue to run as a single-phase machine. In this condition the current taken by the motor will be increased about twofold. Here, then, we have the case of a moderately excessive current brought about by a condition other than insulation failure or overload. If the fuse of a motor working in this condition is rated to carry double the full load of the motor, then it is evident that, through single-phasing, the motor might draw one and a half times full load current from the mains till it burnt out.

Unbalanced Supply Voltage (Three-phase).

A second possible cause of moderately excessive currents may be badly unbalanced supply voltages. It is a fundamental property of an induction motor that it automatically tends to correct voltage unbalance, and it does this by drawing unbalanced currents from the mains, additional to those required for the load. The unbalanced currents help to mitigate the voltage unbalance, but they heat up the motor. An effect of this kind is not likely to be very pronounced, but it might be sufficiently serious with a motor which is delivering its rated load, or perhaps a small overload, to increase the currents above the value of that which can be carried indefinitely. Here we have another case of a moderately excessive current which cannot be dealt with by a fuse which is large enough to allow of the starting current to be carried.

THE THERMAL OVERLOAD TRIPPING ATTACHMENT.

Efficient protection of small A.C. motors has recently been made possible by the development of the thermal overload tripping attachment.

Construction and Operation.

This device comprises a circuit breaker, the latch of which is controlled by the deformation of a bi-metallic strip placed in proximity with a heating coil which carries the motor current. The bi-metallic strip is composed of two metals having different rates of expansion, and the effect of the rise in the temperature of the strip, due to the heat communicated from the heating coil, is to bend the strip, and release the latch holding the circuit breaker in the closed position.

The Action of the Thermal Release.

The action of the thermal release is inherently slower than that of the fuse, for, not only are the parts heated by the load current of greater thermal capacity than a fuse, but the heating of the strip takes place comparatively slowly by radiation from the heating coil. Consequently time lags of over one minute can be obtained, and these time lags are quite consistent, in that they will be repeated with considerable accuracy with the same value of the current.

Time Lag and Trip Setting.

The time lag characteristics of fuses and thermal overload trips are shown in the illustration, and it will be seen that it is possible to set the thermal trip so that the motor is protected from the effect of a continuous overload of 125 per cent., but no tripping will take place with a transient current of four times full load at starting. It will also be seen from the diagram that the time lag of the thermal trip persists for very large overload currents, and that this device is not suitable for providing instantaneous isolation in the event of a short circuit. For this purpose fuses should be used.

The following schedule sets out the relative advantages and disadvantages of the fuse and the overload trip for A.C. motor protection.

	Thermal Trip.	Fuse.
Overload protection	Very efficient	Practically useless
Usual setting ..	125 per cent. of full load	Four times full load
Short circuit protection	Not suitable	Suitable
Maintenance ..	None, automatically resets after operation	Considerable
Accuracy	Within 5 per cent.	Poor, unless frequently renewed

LOCATING FAULTS IN POWER CABLES

By C. Grover, A.M.I.E.E.

The accurate and speedy localisation of faults in cables is of vast importance in electrical work, and in this article Mr. Grover describes some of the principle causes of faults and explains the best methods of locating them

FAILURE of the dielectric in cables usually results in a failure of supply, therefore, accurate tests for the localisation of faults must be made as soon as possible after the occurrence of the failure.

The faults may be situated in the cable itself, a joint, a terminal sealing chamber or in L.T. cables only, a disconnecting box. The same methods, however, are applicable whatever the fault position.

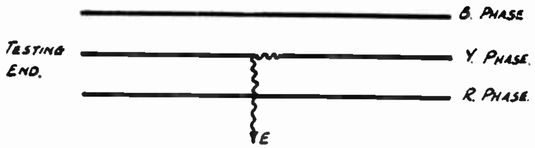


Fig. 1.—A Typical Fault Condition.

This fault can be accurately localised by the Murray loop test, but it is essential that the continuous or the B and R cores are selected for forming the loop.

Principal Causes of Faults.

The principal causes of mains faults are :—

(1) Damage to sheathings and insulation through external blows ;

(2) Subsidences and expansion troubles ;

(3) Defectively constructed joints or service connections.

How the Condition of the Fault can be Determined.

Before any particular test can be applied with an assurance of obtaining a correct result, the precise fault condition should be ascertained. This is best done by making the following measurements :—

(1) The insulation resistance between each conductor of the cable and between each conductor and earth. A megger would ordinarily be used, but if the readings are zero the fault resistance components are not necessarily zero : a further test should be made with a Wheatstone bridge.

(2) The resistance of each loop which can be formed by pairing cores of the cable. The results should be compared with the resistances calculated from the known conductor areas.

From these two sets of measurements, the condition of the fault can be determined.

An Example of a Faulty 3-core L.T. Cable.

Take for example a 0.1 sq. in. 3-core L.T. cable 1,057 yards long, known to be faulty. Calling the red, yellow and blue phases R, Y and B respectively, the insulation tests by a megger were :—

R to Y, B Free = 0.
R to B, Y Free = 100 megs.
Y to B, R Free = 100 megs.

R to Earth or lead sheath = 0 megs.
Y ,, Earth or lead sheath = 0 ,,
B ,, Earth or lead sheath = 100 ,,

The conductor resistance tests by Wheatstone bridge were :—

R looped to Y = 5.32 ohms.
R ,, ,, B = 0.52 ohm.
Y ,, ,, B = 5.35 ohms.
R to lead sheath = 950 ,,
Y ,, ,, ,, = 230 ,,

What the Megger and Resistance Tests Show.

The megger tests and resistance tests on the faulty cores to lead sheath show that the insulation of the B core is sound, but the R and Y cores each have comparatively low resistance earth faults. Solving the simultaneous equations for the loop resistances, the resistance of the Y core is approximately 5 ohms in excess of the value calculated from the B.E.S.A. Specification No. 7 for the resistance of the length of 0.1 sq. in. conductor, whilst the resistances of the R and B phases are in fairly close agreement with this calculated value. Obviously, the yellow core is burnt through leaving a low resistance at the break. The fault condition is therefore represented by Fig. 1.

It will be seen later that this fault can be accurately localised by the Murray loop test, but it is essential that the continuous or the B and R cores are selected for forming the loop. If the discontinuous core is included in the loop the test result will be valueless.

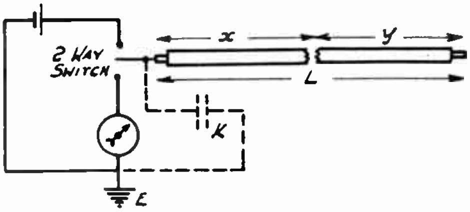


Fig. 2.—How to Connect a Battery Galvanometer and a Well-insulated Two-way Switch.

For making a capacity test where the faulty cable section does not exceed a few hundred yards.

Effects of a Fault Arc on E.H.T. Cable.

As E.H.T. cables, that is those operating at voltages above 3,300, are usually protected by switchgear which operates very rapidly on the occurrence of a fault, the effects of the fault arc are limited, rarely causing severance of conductors or a complete burn-out of all insulation.

Effect of Fault on L.T. Cables.

On the contrary, however, L.T. cables protected by heavy fuses or heavily set-over load circuit breakers are more liable to severe burning on the occurrence of a fault, hence, whilst it is strongly recommended that loop resistance tests be made on faulty E.H.T. cables, they are not so vitally important as in the case of L.T. cable faults. In the latter case, however, failure of supply at any consumer's terminals gives a direct indication of a break.

Faults on Twin or Concentric Cables.

The diagnosis of the fault condition on a twin or concentric cable would be made on similar lines but fewer tests would be required. In the absence of a sound return conductor, single core cables present some difficulty in checking continuity, because if this is done by a Wheatstone bridge resistance test with the far end of the cable conductor earthed, polarisation currents or earth currents at the fault make balance very difficult to obtain. As, however, a fall of potential method would probably be resorted to, the continuity check is of lesser importance, as the accuracy of this test may be unaffected by a conductor break of low resistance.

TYPES OF FAULTS.

Faults can be classified as follows:—

(A) Discontinuities or breaks leaving high insulation.

(B) Discontinuities or breaks leaving low insulation.

(C) Low insulation between conductors only.

(D) Low insulation between conductors and earth only.

(E) Any combination of (A), (B), (C) and (D).

Methods of Localising Cable Faults.

The methods of localising cable faults ordinarily used are:—

(1) Capacity tests; applied to (A) only.

(2) Murray loop test; applied to (C), (D) and (E).

(3) Fall of potential tests; applied to (B), (C), (D) and (E).

(4) Induction methods; applied to (A), (B), (D) and (E).

CAPACITY TEST.

Assuming the faulty cable section does not exceed a few hundred yards and each end of the broken conductor complies with condition (A), connect a battery galvanometer and well insulated two-way switch as in Fig. 2. The galvanometer should be a highly sensitive moving-coil instrument, preferably of the suspended coil type. The two-way switch may be an ordinary two-way tumbler lighting switch of good insulation.

Connecting the Switch and Galvanometer.

This is first put into the position which connects the cable to the battery and left on for a few seconds; it is then switched to the other position which causes the cable to discharge through the galvanometer giving a deflection d_1 which should be made reasonably large by adjusting the battery voltage. Now substitute a $\frac{1}{10}$th microfarad condenser, shown dotted in Fig. 2 (a wireless pattern is quite suitable), for the cable, using the same battery E.M.F. and repeat the switching operations, noting the deflection d_2. If K represents the capacity of this condenser, the capacity of the cable K_x up to the break from the testing end is given by

$$Kx = K\frac{d_1}{d_2}$$

From the other end of the cable, observe the discharge deflections on the cable and condenser similarly and let these be d_3 and d_4 respectively; the capacity of the cable up to the break from this end is

$$Ky = K\frac{d_3}{d_4}$$

If L is the length of the faulty cable in yards

$$x = \frac{Kx\,L}{Kx + Ky} = \frac{d_1\,d_4\,L}{d_1\,d_4 + d_3\,d_2}\ \text{yards.}$$

If there is a sound similar core or cable available d_2 may be observed on this instead of the condenser, which may then be dispensed with and the test made from one end only; whence the fault distance is then :—

$$x = \frac{d_1}{d_2}\,L\ \text{yards.}$$

Good Insulation Essential.

Leakage will upset the accuracy of this test: the cable and apparatus should therefore have an insulation of several megohms.

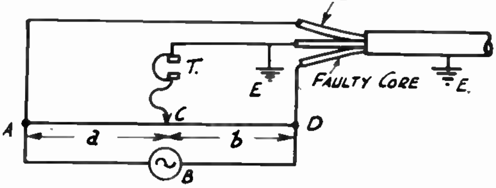


Fig. 3B.—CONNECTION FOR CAPACITY BRIDGE TEST WHERE A SOUND SIMILAR CORE IN A FAULTY MULTICORE CABLE IS AVAILABLE.

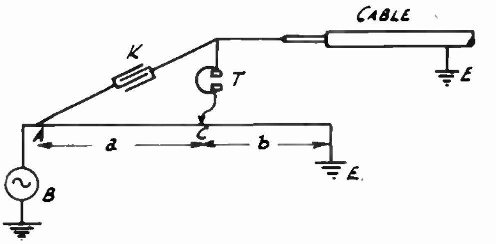


Fig. 3A.—USING A CAPACITY BRIDGE TO TEST FOR A BREAK.

C is adjusted to give minimum sound in headphones.

As the deflections of the usual types of portable galvanometers can only be observed to two significant figures, this test cannot be applied with any accuracy to cables several thousands of yards in length.

If only one side of the break conforms to condition (A), then it is best to use a known length L of sound similar size cable in place of K, with its lead sheath effectively earthed. Then

$$x = \frac{d_1}{d_2}\,L\ \text{yards.}$$

Best Voltage to Use.

The best voltage to use in this test will depend upon the size and length of the cable and the sensitivity of the galvanometer. It should be just high enough to give the largest deflections obtainable. A 60-volt radio H.T. battery is well suited for the purpose, as a wide range of voltages is available for selection.

A Useful Practical Test.

A very useful practical test consists of measuring the charging currents from a 50-cycle supply with earthed neutral into the broken core with an A.C. milliammeter and comparing it with that into a sound core of the cable or that on a known similar length. Representatives figures for the capacities of 3-core power cables are 0.15 to 0.6 microfarad per 1,000 yards per core, with the other cores and lead sheath earthed, which at 250 volts to earth, represent charging currents of approximately 0.012 and 0.048 milliampere per yard respectively. An instrument sealed to one-tenth milliampere provided with non-inductive shunts of

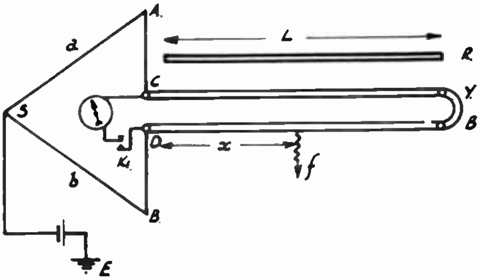


Fig. 4.—A Simple Wheatstone Bridge Circuit.

multiplying powers 10 and 100 would meet most practical cases. If I_1 is the charging current in the broken core, I_2 that into a similar sound core of the cable and L the cable length, the distance to the break is

$$\frac{I_1}{I_2} L.$$

Using a Capacity Bridge to Test for a Break.

The most convenient practical test for a break is made with the capacity bridge. In Fig. 3A, A E represents a non-inductive slide wire or resistance box; this may be improvised by stretching a few feet of 20 S.W.G. resistance wire between two points. K, is a condenser of known capacity and B a buzzer energised by a few dry cells. T is a pair of medium resistance headphones. Let Kx represent the capacity of the cable up to the break. By moving C along the slide wire a point of silence or minimum sound can be found dividing A E into a and b length units, whence :—

$$Kx = \frac{Ka}{b} \text{ microfarad.}$$

It will be noted that the factor $\frac{a}{b}$ is the reciprocal of the corresponding factor where Kx and K are resistances as in the Wheatstone bridge, because a high capacity acts as a low resistance and vice-versa. A convenient value for K is 0.5 microfarad.

If the break has a high insulation from each end of the cable K need not be known. Make a test as Fig. 3A from each end, calling the slide wire divisions a and b, and a_1, b_1. If L is the cable length in yards

$$x = \frac{L\,a\,b_1}{a_1 b + a\,b_1} \text{ yards,}$$

x being reckoned from the cable end from which a and b were observed.

How to Calculate the Fault Distance if Capacity per Yard of the Cable is Known.

If the capacity per yard of the cable is known from the maker's certificates, the distance to the fault is found by dividing this value into Kx. If this unit capacity is not available it can be determined by substituting a known length of similar cable for the faulty cable in Fig. 3A.

If a sound similar core in a faulty multicore cable whose length is L yards is available, then connect as Fig. 3B. By similarly adjusting the point C, where A D now represents the slide wire,

$$x = L\frac{a}{b} \text{ yards.}$$

It would be incorrect to use another conductor of a faulty concentric cable, because the capacity of the conductors per unit length is dissimilar.

MURRAY LOOP TEST.

This test is a simple Wheatstone bridge circuit represented in Fig. 4. A loop is formed by joining solidly together the distant ends of the faulty core and a sound similar core. Fig. 4 assumes this condition in a 3-core cable of which R, Y and B represent the three conductors, the latter being faulty.

When the position of S is adjusted so that no galvanometer deflection occurs,

$$x = \frac{2\,b\,L}{a + b} \text{ yards} \ldots\ldots\ldots\ldots\ldots (1)$$

where L is the length of the cable in yards.

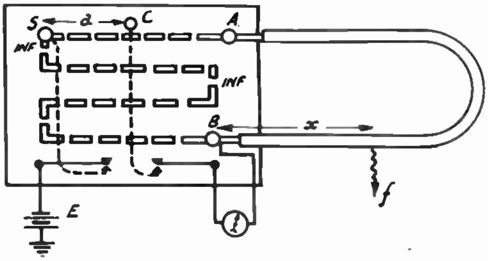


Fig. 5.—Connections with a Post Office Pattern Bridge.

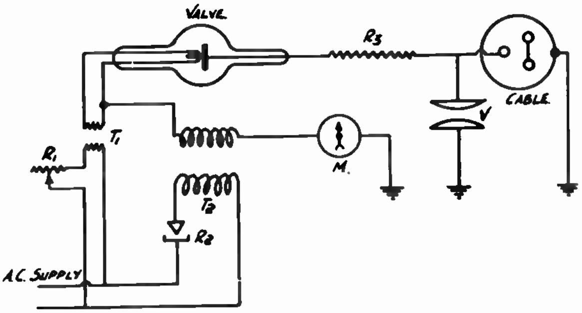


Fig. 6.—CIRCUIT FOR APPLYING MURRAY LOOP TEST TO HIGH-RESISTANCE FAULTS.
Showing the use of themionic rectifying valves.

Simplest Way to Carry Out the Test.

The simplest way to carry out this test is to connect securely and stretch out straight a few feet of approximately No. 20 S.W.G. resistance wire across the ends of the cable loop and connect a sensitive galvanometer across the cable ends, a suitable galvanometer being a portable suspended pattern d'Arsonval galvanometer, provided with a pointer and mirror, having a coil resistance of 180 ohms and an approximate sensitivity of 0.2×10^{-6} ampere per scale division on the pointer, and 5×10^{-9} ampere per millimetre at a scale distance of one metre when used as a reflecting instrument.

The unearthed end of the battery E can be connected to the blade of a penknife, the sharp edge of which is slid along the resistance wire to a position S at which the galvanometer deflection becomes zero.

If the lengths of the stretched wire S A and S B are a and b inches respectively, x is given by formula (1).

Connection Forming Loop Must be Short.

The connection forming the loop at the distant end must be short and as nearly as possible of the same sectional area as the cable conductors.

If it is impossible to make a short loop, the length thereof must be added to 2L.

Attach the Stretched Wire and Galvanometer Leads Direct to Cable Ends.

Whenever possible, the stretched wire and galvanometer leads should be attached directly to the cable ends. If this is not practicable, the connections A C, D B, Fig. 4, must be as stout and short as possible. As only light wires are necessary for the galvanometer these can be conveniently connected to the cable ends. If this is not done the "equivalent length" of the connecting leads A C, D B must be added to 2L.

What to do if Conductor Sizes Vary.

Formula (1) assumes that the resistance per yard of the cable loop is uniform throughout. If the conductor sizes vary, then one must be converted to the equivalent length of the other; for instance, if in Fig. 4 the R and Y were 19/.083 (0.1 sq. in.) conductor and the B 19/.064 (0.06 sq. in.), it will be necessary to convert the length of the Y to an equivalent of the B which is

$$L \times \frac{(.064)^2}{(.083)^2}$$

The equivalent loop length in terms of .06 sq. in. conductor is then

$$L\left(1 + \frac{(.064)^2}{(.083)^2}\right)$$

which will be substituted for 2L in formula (1).

NOTE.—It would not be convenient to convert the B conductor to an equivalent length of the Y, because x would be given in an equivalent length of 19/.083, which must be converted back to terms of 10/.064.

Why the Position of the Galvanometer and Battery Should not be Reversed.

Although theoretically it is possible to reverse the position of the galvanometer and battery, there are two objections to this in practice: (1) The fault is rarely free from polarisation or earth currents which do not affect the test if the battery E is in the fault circuit, but which may cause violent fluctuations and even damage to the galvanometer if it is connected in the fault circuit. (2) If E is a storage battery there is a risk of overheating the slide wire A S B, which may give rise to a thermo-electric E.M.F. which will introduce errors.

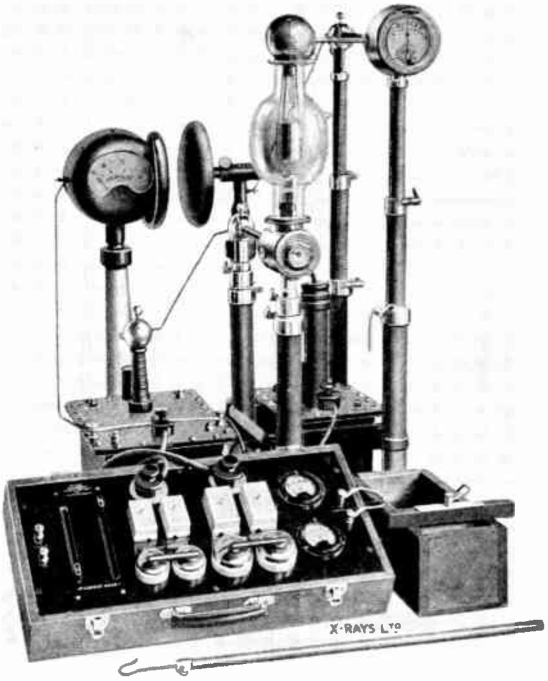


Fig. 7.—A COMPLETE SINGLE-VALVE TESTING SET. Suitable for pressures up to 50/60 kV. D.C. capable of breaking down faults and supplying the localising current on cables up to 33 kV. working pressure. (*Messrs. X-Rays, Ltd.*)

As, however, it is sometimes necessary to resort to reversed positions of battery and galvanometer, due attention should be given to these points. The galvanometer key K must be used and closed before the battery circuit is closed. If a fairly steady deflection persists, balance must be effected by adjusting the position of S until this deflection remains unaffected when the battery is switched on. This is called balancing to a " false zero."

Testing Sets Incorporating Slide Wire Principle.

A large variety of testing sets incorporating the slide wire principle are available, the simplest of which embodies a resistance wire about a metre long stretched above a scale of one metre divided into millimetres, with a slider which makes contact with the stretched wire. If A B (Fig. 4) represents this wire, $a + b$ will always equal 1,000, whence x is $\frac{2b\ L}{1,000}$ b being in millimetres, and always reckoned from the end of the slide wire to which the faulty core is connected.

What to do When Dealing with Long Lengths of Cable.

For long lengths of cable the slide wire must be longer, for assuming balance can only be accurately read to one slide wire subdivision, the possible error in a one metre wire is 1 yard for every 1,000 yards of loop length. Instruments are available in which the slide wire is subdivided into 10,000 parts giving an accuracy of 1 yard per 10,000 yards of loop. It is necessary, however, that the galvanometer is sufficiently sensitive to respond to one division variation from the point of balance to make the best use of the slide wire, that the fault resistance must not exceed a few hundred ohms and that adequate battery power is available. For fault resistances of a few thousand ohms, a 60-volt wireless battery or better still, a 1,000-volt hand generator capable of delivering 50 milliamperes is useful.

If a 3-wire D.C. supply is available having an earthed neutral, a bank of lamps connected between S (Fig. 4) and an outer in place of the battery E will give good results, but all apparatus should be adequately insulated or errors will arise through leakage.

Using Two Arms of a Wheatstone Bridge.

Instead of a stretched wire bridge, two arms of a Wheatstone bridge may be connected between A and B (Fig. 4). Fig. 5 shows the connections with a Post Office pattern bridge. By first connecting the battery terminal shown earthed to A the resistance of the loop can be checked.

In making the localisation test all plugs are inserted in the arm C A. The arm S C and the variable arm S B are then adjusted to balance, each being kept as high as possible. If S C and S B are represented by a and b ohms respectively, formula (1) gives the distance of x in yards.

The observations already made respecting the changing over of battery and galvanometer positions apply equally, but it is unwise to use a supply from D.C. mains instead of a battery as a serious risk of burning out the resistance coils is involved.

High Resistance Faults with L.T. Cables.

When the fault resistance is several thousand ohms any of the foregoing loop tests fail, as sufficient current cannot be passed through the galvanometer. With L.T. cables, the application of 1,000 volts A.C. from a small transformer will generally reduce the fault resistance to a sufficiently low value for a successful loop test.

High Resistance Faults in E.H.T. Cables

High resistance faults in E.H.T. cables present a more difficult problem; often they will sustain the normal working voltage for days and in the absence of a testing transformer the risk of damaging the windings of spare supply transformers precludes the application of voltages in excess of the working pressure.

Using Thermionic Rectifying Valves to Reduce Fault Resistance.

In these circumstances the fault resistance can only be reduced by the application of high-tension D.C. voltages obtained from thermionic rectifying valves, the operation of which depends upon the principle that a highly evacuated space containing two electrodes, the cathode of which is incandescent and the anode comparatively old, possesses a unidirectional conductivity. The cathode is rendered incandescent from a source of supply insulated from earth for the pressure to be applied to the cable.

In Fig. 6, T_1 is a transformer with a highly insulated secondary winding which incandesces the valve filament. T_2 is a step-up transformer of small capacity (say 1 to 3 kVA.) and R_2 is a water resistance which enables regulation of the output voltage of T_2 to be made. M is a moving coil milliammeter which will record the average current passing through the valve and cable.

The latter is indicated at the right of Fig. 6, with one conductor connected to the valve, the other cores and the lead sheath being earthed. R_3 is a resistance of the order of 200,000 ohms for protecting the valve against excessive currents. This can, however, be dispensed with when a fault resistance is reduced to a low value. In effect, the H.T. transformer secondary winding T_2, the valve R_3 and the cable which represents a condenser, form a simple series circuit; as the valve will only pass current in one direction, a charge will accumulate in the cable core, if the insulation is sound; if not, a unidirectional pulsating current will traverse the leakage path, or cable fault.

Fig. 8.—HIGHLY INSULATED SLIDE WIRE BRIDGE AND GALVANOMETER.

This is specially designed for use with high tension D.C. (*Watson and Sons* (*Electro-Medical*), *Ltd.*)

Applying the Murray Loop Test to High Resistance Faults.

This principle is used in applying the Murray loop test to high-resistance faults. Valve apparatus similar to Fig. 6 replaces the battery E in Fig. 4, and a specially insulated slide wire and galvanometer is used. Cable faults having a marked tendency to seal up, may require the application of several thousands volts pressure initially to break them down after which currents up to 100 milliamperes can be steadily passed by the rectifying apparatus, which allows a very accurate loop test to be made.

Precautions to be Observed when Breaking Down a Fault.

It is always advisable to have an electrostatic voltmeter, V (Fig. 6), connected to the cable end so that excess pressures can be avoided during the process of breaking down a fault. D.C. pressures should not exceed three times the normal working pressure of the cable to earth, and on very old cables, twice the working pressure. Further, when breaking down a fault the cable should be disconnected entirely from switchgear and busbars.

Before a fault is fully developed, a charge of several thousand volts can be built up in the cable, which at a certain pressure will suddenly arc over at the fault and discharge the cable. This process may repeat itself several hundred times, the pressure at which the fault arcs over gradually decreasing until no voltage accumulates in the cable, but steady currents of 50 to 100 milliamperes can be passed, as recorded by the milliammeter, according to the size of step-up transformer and the type of valve used. No attempt to localise the fault should be made until this condition obtains, for if there is any tendency for the fault temporarily to reseal itself there is a risk of severe shock to the operator and damage to the apparatus. Currents of 50 to 100 milliamps. are ample for an accurate loop test if the slide wire and galvanometer have resistances of the order of 10 ohms and 20 ohms respectively.

Single Valve Testing Set.

Fig. 7 shows a complete single-valve testing set suitable for pressures up to 50/60 kV. D.C. capable of breaking down faults and supplying the localising current on cables up to 33 kV. working pressure.

Fig. 8 illustrates the highly insulated slide wire bridge and galvanometer specially designed for use with high tension D.C. The long rods on the slide wire are made of ebonite for the safe manipulation of the sliding contact and the galvanometer short circuit key. The slide wire is divided into 1,000 parts easily read to half a division and resistances of 1, 5 and 10 times the slide wire resistance are incorporated in the instrument, so that the slide wire can be lengthened by these multiples when the fault is near the end of the loop. This enables a reading of three significant figures to be observed; otherwise in this circumstance, the accuracy of observation on a long loop would be small and consequently the calculated fault distance would probably be several yards in error.

In using the apparatus shown in Figs. 7 and 8, the connections would be as in Fig. 4, except that the output side of the valve in Fig. 7, would be connected to the sliding contact of the slide wire.

The precautions previously mentioned as regards low resistance connections in the loop and conversion to equivalent lengths must be observed.

Loop Tests on Branched Cables.

On a cable having solidly connected branches, a loop test should be made with the various branches looped at their ends in turn, the other branch ends being left open circuited. A moment's reflection will show that if a fault is in an open circuited branch, the loop being closed on another sound branch, then the fault position will be given at the T joint of the open circuited branch, which would not be correct.

"Short" Between Two Cores.

If the fault is a "short" between two cores and not an earth, the loop test gives excellent results, provided a good return is available, as in Fig. 4 one of the "shorted" cores is used instead of earth. In Fig. 1, for example, the loop would be formed by the B and R phases and the end of the battery shown earthed in Fig. 4 would be connected to the Y phase instead. The testing apparatus should be insulated from earth in this case.

A later article will deal with fall of potential tests, and testing by the induction method.

Correspondence

The Editor invites correspondence from readers on any subject of general interest to members of the electrical engineering profession. Letters should be addressed to THE EDITOR, The Practical Electrical Engineer, 8-11, Southampton Street, Strand, W.C.2.

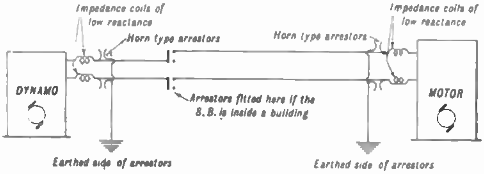
Protecting a Building from Lightning and Line Surges.

Sir,—Can you tell me how to protect a building which receives its electrical supply from an overhead transmission line, from the effect of lightning and line surges?

R. M. C. (Newcastle).

Horn type spark gap arrestors should be fitted at the entry of the lines to the dynamo and motor shed.

Should the switchboard be fitted inside a building, the incoming and outgoing lines should be also fitted with arrestors.



How Horn Type Spark Gap Arrestors should be Fitted.

The arrestors should be fitted close to the point of entry of the lines into the building, and may be clamped on to the lines, thus avoiding the necessity of making joints.

The ends of the lines should be coiled in a few turns to act as a low reactance impedance coil: this is, in effect, a high resistance to oppose the passage of H.F. currents, due to lightning discharge, into the apparatus and machinery contained inside the buildings.

The spark gap in the arrestors should be small, owing to the low pressure nature of the distribution.

An authority on lightning conductors and protection of buildings from damage due to lightning discharge, is Sir Oliver Lodge.

His book entitled, "Lightning Conductors and Lightning Guards," may be consulted with advantage.

Heavy Synchronous Motors.

Sir,—Can you tell (1) What will happen to a heavy synchronous motor when the exciter circuit is suddenly switched off, with the motor running at normal speed? By exciter current I mean the D.C. circuit supply current to the field of the synchronous motor. (2) Is there any other method except by using a transformer to start the heavy synchronous motor?

A. K. Bhaumik (Stretford).

(1) *A definite answer cannot be given to this question because no data are available of the design of the motor, the nature of the load, nor of the supply system. Full data would be required on all these points before any definite statements could be made.*

We may assume, however, that the synchronous motor is of the modern self-starting type with a squirrel-cage winding in the pole faces. We will also assume that the supply system to which the motor is connected is capable of maintaining its voltage and frequency when large drafts of current are taken from the mains.

The effect of opening the exciting circuit is to convert the machine into an induction motor. The magnetising current, which normally was supplied from the direct-current exciter, will now have to be supplied from the A.C. mains. Thus an increase of current will occur, and the power factor will be reduced.

The motor will, of course, fall out of step; but whether or not it will continue to run slightly below synchronous speed as an induction motor will depend upon (1) *the pull-out torque corresponding to induction-motor operation;* (2) *the actual load on the motor.*

Due to the relatively large air gap the pull-out torque when operating as an induction motor will be lower than that of a true induction motor of similar size, and in the present case may be much less than the pull-out torque when operating as a synchronous motor; in fact, this torque may vary between one-half of full-load to twice full-load torque according to the design of the pole-face winding.

Hence, if the motor were lightly loaded it would probably continue to run as an induction motor.

Due, however, to the flywheel action of the heavy machine, the speed will fall gradually to its steady sub-synchronous value, and, in consequence, when the excitation is removed, the stator current will not rise suddenly to its steady value, but may take several seconds to reach this value.

(2) Synchronous motors are usually fitted with a squirrel-cage pole-face winding for the double purpose of preventing hunting (by damping sudden irregularities in the speed) and to provide sufficient starting torque to enable the machine to start against light load when the stator winding is connected to the supply system and the field winding is unexcited. In order to limit the current taken from the supply system, the motor is started at reduced voltage. Any method of reducing the voltage may be used (e.g., a series resistance, a series reactance, or a transformer), but the best method is the transformer, as the current taken from the supply is reduced as well as the voltage applied to the motor.

In some modern synchronous motors in which high torque is required at starting, the pole-face winding takes the form of a polyphase winding similar to the rotor winding of a slip-ring induction motor. This winding is connected to slip-rings in the same manner as in an induction motor. The motor is started at full voltage (i.e., no transformer is used) with external resistance connected to these slip rings, and this resistance is cut out in steps to bring the motor up to nearly synchronous speed. The motor then pulls into step when excitation is applied to the field winding. When running, the slip rings are kept permanently short circuited, so that the pole-face winding acts as a damper winding.

It should be noted that in this type of synchronous *motor, the rotor is of the salient-pole type and has two distinct windings, viz., the ordinary excitation winding and the pole-face winding. The motor, therefore, differs considerably from a synchronous-induction motor. Further details can be found in the* Transactions of the American Institute of Electrical Engineers, *vol.* 50 (1931), *p.* 600.

Rewinding a Small Motor.

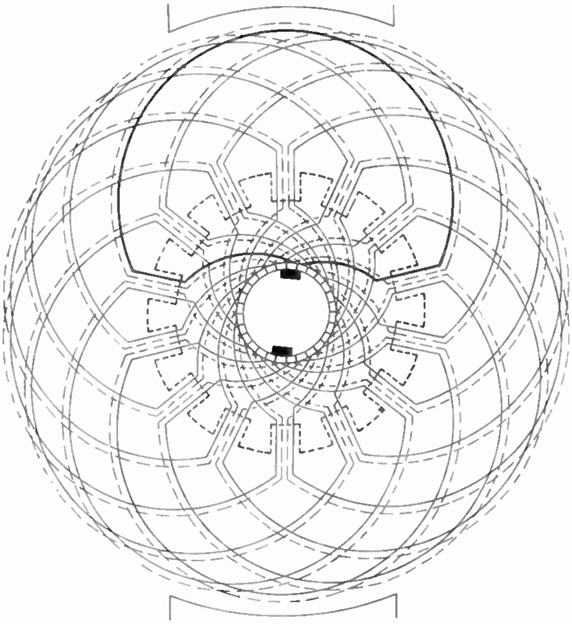
Sir,—Would you be good enough to inform me how to wind a motor armature which has 14 slots and 28 commutator segments for 110 volts D.C., speed 3,000 r.p.m.?

S. W. McLoughlin (Holmes Chapel).

The winding data relates to a motor having an armature $1\frac{11}{16}$*-in. diameter, with* 14 *slots and a* 28*-segment commutator. The motor is to work on a D.C. supply of* 110 *volts.*

A motor of this type must have a duplex armature winding, because there are twice as many commutator segments as there are slots on the armature. The accompanying diagram shows the completely wound armature. There are 28 *coils of* 40 *turns each of* 29 *S.W.G. double-silk covered wire. The first half of the winding is shown in the diagram by full lines, while the second* 14 *coils are shown by dotted lines. One coil is emphasised in the diagram to indicate the span of the coils. The order of winding the coils is as follows:—*

Wind round slots 1 *and* 7, *then* 13 *and* 7, 13 *and* 5, 11 *and* 5, 11 *and* 3, 9 *and* 3, 9 *and* 1, *then repeat.*



The Completely Wound Armature.

For the fields, wind two coils of 3,900 *turns each, with* 38 *S.W.G. enamel-covered wire, on wooden formers. After binding the coils with empire tape, they are transferred to the magnet. The fields are connected in series with one another and in parallel with the brushes or armature. In the diagram the brushes are shown in the neutral position with respect to the field magnets, but under working conditions the brushes should be displaced from the neutral position in the opposite direction to the rotation of the machine. The field coils will require about ¾ lb. of wire and the armature* 3-4 *ounces.*

Fixing Wall Spikes.

Sir,—Can you tell me how wall spikes are fixed in a wall, where the public supply is on the overhead system and house services are taken straight from a pole and fixed on the house walls by means of small shackle insulators? If cement is used what is the correct mixture?

H. Stevenson (Brotton).

Distribution line fittings fixed to houses are secured in a variety of ways, depending on the nature of the fitting and the class and condition of the wall. Ordinary wall nails may be used, driven into the mortar, or screw bolts screwed into a drilled hole of the correct size. When rag bolts are used, they are grouted in with cement. The actual mixture of cement is of little importance for such work; almost anything from neat cement to an ordinary 3:1 *mixture of sand and cement can be used. If quick setting cement is used, wires can be strained the following day. If the bolt is a tight fit in the hole made, and the strain is almost entirely a side strain and not an outward pull, wires could be fixed before the cement has set.*

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