Radio Relay Systems Explained

The PRACTICAL ELECTRICAL ENGINEER

A MONTHLY MAGAZINE OF ELECTRICAL PROGRESS

VOL. 1.—No. 12

AUGUST, 1933

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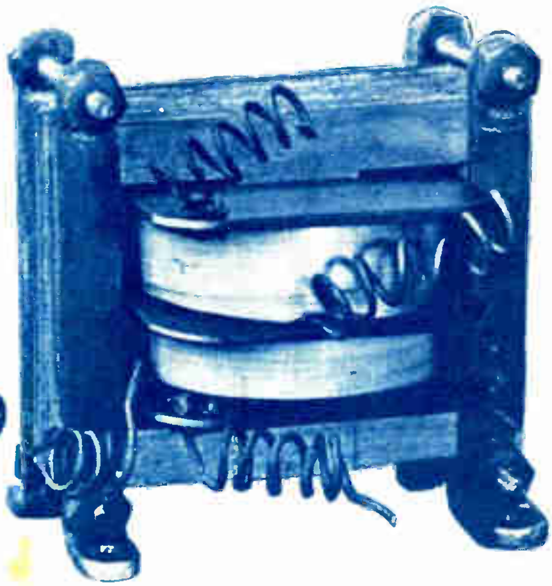

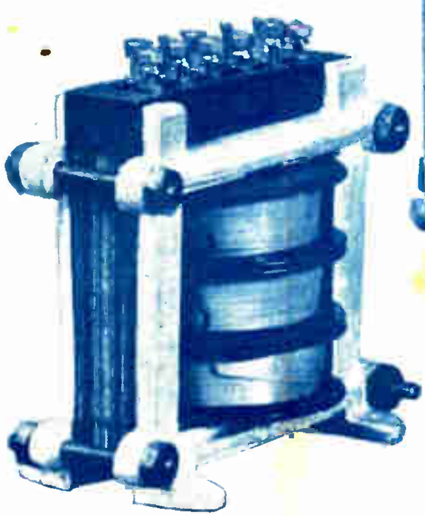

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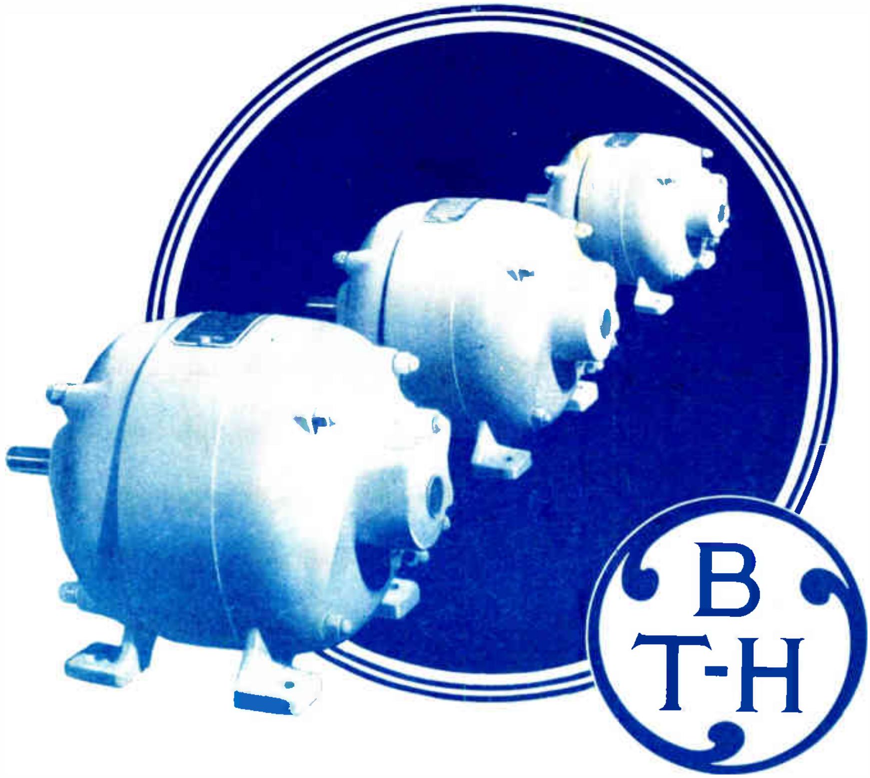

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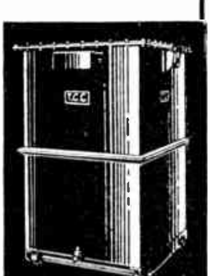

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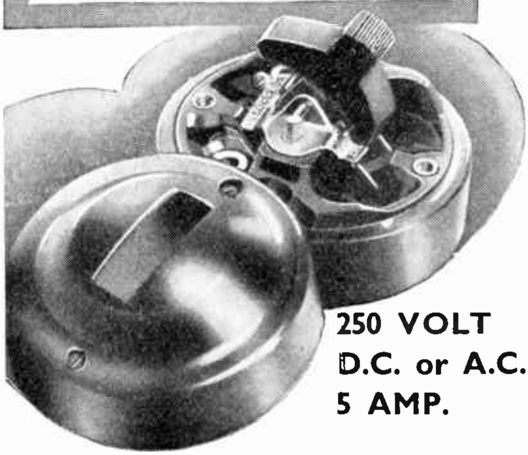

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The PRACTICAL ELECTRICAL ENGINEER

A MONTHLY SURVEY OF MODERN PRACTICE IN ELECTRICAL ENGINEERING

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Radio Relay.

Many readers will have noticed the recent issue of shares in connection with the Radio Relay Company which has been operating successfully for some time in the Leeds and Huddersfield district. The scheme consists in having a central receiving apparatus with a suitable amplifying panel wired up to the houses of subscribers in the neighbourhood. Each subscriber is provided with a loudspeaker, volume control and selector switch, enabling him to choose any of two or three programmes. Such a scheme has obvious advantages in certain cases, but it does not seem likely to prove a serious competitor to the manufacturers of high-class wireless receivers, any more than the motor bus has proved a competitor to the private motor car. Technical details of the scheme are given in an article beginning on page 529, and in view of the developments which are taking place in the near future we propose to follow this by a short series of articles dealing with other practical aspects of the subject.

An Amendment to the Electricity Supply Act.

A Bill to amend Section 16 of the Electricity (Supply) Act, 1919, and Section 21 of the Electricity (Supply) Act, 1922, was recently presented by Mr. George Hall. These particular amendments have a bearing upon the question of compensation payable to employees of authorised electricity undertakings who are adversely affected by the development of the Grid schemes. The Memorandum on the front of the Bill states :—

" Arising out of a claim for compensation under the provisions of Section 16 of the Electricity (Supply) Act, 1919, as amended by subsequent enactments, with respect to redundant officers and servants, the court has held that the time limit of five years during which a case for compensation must arise commences on the date when the improvement scheme, upon approval by Parliament, comes into force. The case which was before the court arose out of a scheme covering a large number of undertakings, and some redundant stations were not and could not be closed until after the expiration of five years. Consequently certain claims for compensation were rejected.

" The sole purpose of the Bill is to provide that the time limit of five years shall date from the period when operations under a scheme with respect to a particular undertaking actually commence."

Section 2 of the new Bill seeks to confer on the Electricity Commissioners power to decide whether " any cessation of operation or change in the method of operation of a generating station was in pursuance of a scheme agreement or arrangement." There are, we feel sure, good and sufficient reasons for this amendment, but we suggest that the statement which appears under the heading " Memorandum," and which, presumably, is given for the guidance of Members of Parliament and others interested in the Bill, is a little misleading.

Protecting Electrical Plant Against Fire.

Now that so many districts are connected to the Grid the breakdown of heavy electrical machinery such as is installed at trans-

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former stations and substations is attended by enhanced risk of fire.

Although protective appliances have been brought to a high state of perfection, there is still the fact that the whole power of the Grid is momentarily behind any weak point in the system. The rupturing capacity of main switchgear and circuit breakers has had to be greatly augmented for this reason. In view of this, the subject of fire protection is one which is of special interest to electrical engineers, and the article beginning on page 564 will, therefore, be found well worth perusal.

Croydon's Enterprise.

Fires which may not be of electrical origin, but which occur in buildings situated near the main or subsidiary Grid network might, it was at one time thought, introduce an additional danger to firemen through the possibility of the jet of water from the fire-hose coming in contact with an overhead line having a voltage of, say, 132,000 volts. A brief account of the tests recently conducted by the Central Electricity Board, in conjunction with the Croydon Fire Brigade, will be found at the end of the article on Fire Protection Apparatus. They show conclusively that no danger from this source need be feared providing proper precautions are taken regarding the size of the jet. Where the jet is broken up into spray the possibility of shock is negligible. If the overhead line is very near the burning structure only small-diameter jets, $\frac{5}{8}$-in. nozzle or less, can be used with safety. If the distance is 60 ft. or more, jets from nozzles $1\frac{3}{8}$-in. diameter can safely be used.

Heating Water by Electricity.

In our last issue we drew attention to the need for a storage battery capable of storing electricity and yet comparatively light in weight. This is a problem which has baffled electrical engineers for the past 30 years. There is, however, a method of storing electrical energy which is very simple and highly efficient. This is the thermal system. An immersion heater fitted to an existing hot-water tank will store electrical energy in the form of heat during the off-peak hours, so that the householder has a supply of hot water whenever he needs it. The heating of water by electricity in this way has a great future, and Mr. Hickmott's article, which begins on page 540, is, therefore, of more than passing interest.

An Interesting Application of Wireless.

An interesting method has been devised by the L. M. Ericsson Co. by which a lecture or speech can be heard in several languages.

This new apparatus was installed at the World Power Conference which took place in Stockholm. The Conference Hall had a transmitting aerial fixed round the walls. Whilst the speech was in progress interpreters translated it into the various languages, and each interpreter's words were "put on the ether" on a different wavelength. Members of the audience were each provided with a small receiving set and frame aerial which could be tuned to the wavelength corresponding to any selected language.

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Binding of Volume I

THE present issue of the Magazine completes the first volume. Readers who wish to have their sets bound for reference are advised to obtain the Publisher's binding cases, which can be ordered through any newsagent or bookseller, price 2/6, or they will be sent direct, post free, price 3/-, complete with Index. Additional copies of the Index may be had on application to the publishers price 6d. each post free. All postal enquiries and orders relating to Binding Cases and Index should be addressed to The Publisher, "The Practical Electrical Engineer," 8-11, Southampton Street, London, W.C.2.

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RADIO RELAY SYSTEMS

By C. W. Watson

The average listener welcomes simplification of wireless reception and this explains the popularity of relay services in many parts of the country. The author is engaged on the work of installing radio relay systems and he describes in this article the various methods used for transmitting broadcast programmes from a relay station to its subscribers

RADIO relay service, although comparatively new to this country, has been in operation on a large scale on the Continent, particularly in Holland, for the past seven or eight years. Various methods of transmission of programmes may be employed, the choice of these depending largely upon local conditions.

The essential features of a radio relay system are, of course, a receiving station, amplifying equipment, and a medium of transmission from the relay station to the premises of the subscriber.

Location of the Relay Station.

For transmission purposes it is desirable that the station be situated in an accessible part of the most densely populated portion of the area which it is to supply. For obvious reasons, it may be difficult or even impossible to secure satisfactory reception in such a position, and it is therefore often found necessary for the amplification to be carried out in the centre of the town and the receiving station erected in a more remote situation, the two being connected by land line.

Fig. 1.—Radio Relay Station Distribution Mast. (*By courtesy of J. S. Ramsbottom & Co., Ltd., Bow Street, Keighley.*)

DISTRIBUTION OF PROGRAMMES.

By Overhead or Underground Lines.

In Holland, where the streets and roads are not so well made up, it is more easy to run underground wires than in this country, where the capital outlay involved would not be justified. The commonest method of distribution here is, there-

World Radio History

fore, by overhead lines, these being supplemented to a large extent in flat dwellings and large blocks of property by lead-covered cables run along roofs or walls as may be necessary. Programmes may be transmitted by low frequencies or by means of carrier current.

Transmitting Several Programmes on One Line by Means of "Carrier Current."

This term denotes the use of modulated high frequency for transmission of signals. It is used to a large extent in Post Office engineering circles for simultaneous transmission of several signals or messages along the same lines, separate frequencies being employed for each of the different signals. Almost any number of frequency bands, more commonly referred to as channels, may be used, provided frequencies are selected which will not heterodyne each other.

This method is used in a comparatively few cases where alternative programme systems are in operation. Its advantages are that several frequency channels may be employed on one pair of lines. These advantages, however, are more than counter-balanced by the necessity of installing rectifying equipment on the premises of the subscriber, and as it is very impractical to transmit signals by carrier current with sufficient power for operating the loudspeakers, further amplification becomes necessary.

Low Frequency Transmission.

The main function of a radio relay service being to simplify the reception of broadcast programmes for the subscriber, the use of apparatus, except at the relay station, is to be avoided. The result is that low frequency working is undoubtedly the most popular system employed. In all cases of programme distribution a balanced metallic circuit must be maintained, earth return systems being contrary to the regulations under which licences are granted.

Two-wire, One Programme Distribution.

For transmission of one programme only, one pair of lines is employed, these being suspended and insulated in a similar manner to ordinary telephone circuits. One pair of lines leaving the relay station may supply quite a large area and instances of 500 subscribers or more being serviced by a single pair are not uncommon. To facilitate the location of faults, the branches of such a line must necessarily be arranged through distribution points and may be fitted with fuses which break down with excess of signal current in case of short circuit, cutting out the affected area without seriously interfering with the service in general.

Low Frequency and Superimposed Carrier Current Transmission.

A few systems in this country have operated with one programme transmitted at low frequency and the alternative programme superimposed on the same line by carrier current. Attempts to use the loudspeaker coils as the tuning inductance in the detector circuit and other interesting experiments have been made with varying measures of success, but most systems employing these methods have, after an experimental period, changed over to all low frequency working.

Two programmes may be transmitted by means of three wires using half-phantom circuit or by four wires using two complete circuits.

Method of Preventing Induction in the Four-wire Low Frequency System.

In the four-wire system, which is now fairly common, induction takes place between the lines carrying the different programmes. As this induction cannot easily be prevented, the lines must be transposed at intervals in such a manner that the currents induced in one portion of the lines are balanced out by those induced in the next. In telephone practice, transpositions are arranged at intervals of one quarter of a mile to balance out cross-talk, but owing to the heavier currents employed in radio relay work, more frequent transpositions are desirable. Where the distance between the transpositions is too great, it is not unusual for cross-talk to be audible in the centre of a run and inaudible at the extremities, this being accounted for by the resistance of the conductors.

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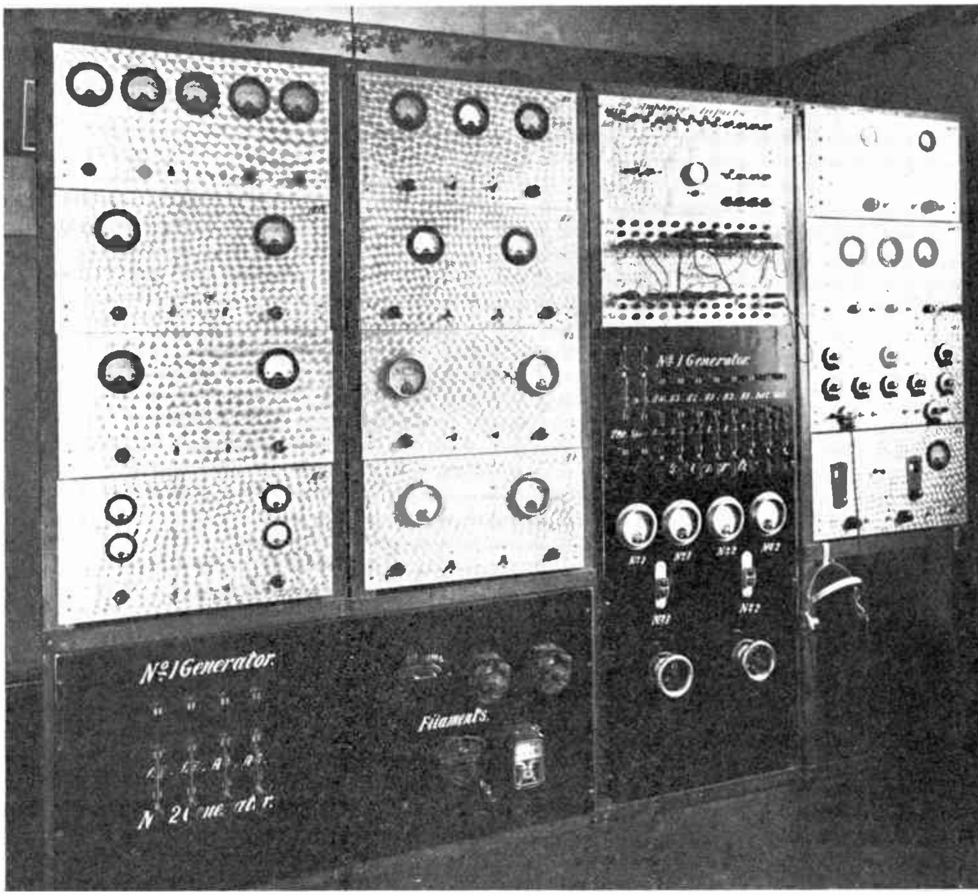

Fig. 2.—Relay Station Equipment for Supplying Broadcast Programmes to 2,000 Subscribers.
Taking each stand from the bottom and commencing from the right, the units are as follows: *DX Receiver, Dual Receiver* (receiving two programmes from one aerial), *Two Intermediate Amplifiers.* *Generator Control Panel* with remote controls, regulators, and change-over switches for generator and stand-by. *Line Control Panel* with plug and jack arrangement for distribution of programmes and series jacks for measurement of outputs.
Programme Control Panel with faders from receivers to intermediate amplifiers and switches from intermediates to power bank, also hot-wire ammeter for measurement of signal current by plugging into series jack. *Power Meter and Filament Switch* with time switches. *Four Amplifiers* capable of running 250 loudspeakers each, the top one giving a direct reading of voltage between anode and filament. *Four Amplifiers* as above, the bottom one giving direct reading of anode current and grid bias voltages for matching up the valves, and top one, capable of running 500 loudspeakers. (*By courtesy of J. S. Ramsbottom & Co., Ltd., Bow Street, Keighley.*)

Three-wire System Relaying Two Alternative Programmes.

In the three-wire system, one programme is arranged across two of the wires, the alternative programme being transmitted by the third line. Nos. 1 and 2 lines are used in such a manner that they are at equal potential, so that no interference with No. 1 programme takes place. This method usually entails the use of resistances or condensers which increase the load on No. 1 Programme and also affect the quality of reception.

The three-wire system with its disadvantages is not very popular. It is found almost as easy to erect four wires

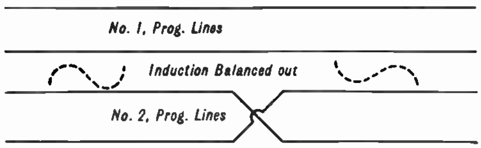

Fig. 3.—HOW INDUCED CURRENTS ARE BALANCED OUT IN FOUR-WIRE DISTRIBUTION SYSTEM.

The lines are transposed at intervals in such a manner that the currents induced in one portion of the lines are balanced out by those induced in the next.

as three, and the result is that most dual programme systems are now operating on two pairs of conductors.

Method of Superimposing Third Programme on Four-wire System.

A third programme may be superimposed on the four-wire system in such a manner that No. 1 pair act as one conductor and No. 2 pair as the other, the potential across each pair being equal in respect of No. 3 programme, whilst full signal voltages are imposed between one pair and the other.

METHOD OF INSTALLATION.

The lines carrying the programmes are looped as far as possible from one block of property to another, separate spurs being tapped off for each street or block. The method of connection is similar to the old tree system of electric lighting, each subscriber being merely tapped across the lines.

Isolation of Faults by Use of Fuses.

Various methods of isolating faults in installations have been employed, the commonest being the insertion of fuses which break down in the event of an over-load on the tapping and open circuit the subscriber's wiring, the remainder of the service being unaffected. In a small system, the station operator may be able to observe when a fuse has blown, but has no means of locating the affected installation beyond knowing to which line it is connected until receiving a report from the subscriber. These fuses may be inserted under the screw cover of a pot-headed insulator, or in a suitable box on the bracket or masonry, but are more usually fitted inside the premises as near to the point of entry of the lead-in as possible.

Use of Resistance or Capacity for Isolating Faults in Distribution.

Other methods of protection, not quite so common, are the inclusion of resistance, or capacity, or a combination of both, in each subscriber's circuit. In the case of a dead short circuit in the subscriber's premises, the load on the line is limited by the value of the resistances or condensers, such a fault only affecting the system to a similar extent as the addition of several loudspeakers. The objection to this method is that fault location is not so easy and that in the case of an intermittent load or short circuit, the subscriber is apt to tolerate inferior results from his loudspeaker for some time before reporting the matter, whereas if a fuse is inserted, immediate attention is drawn to it, the trouble rectified and a more efficient service is maintained.

A further objection to the capacity method is that the quality of reproduction of the lower frequencies is affected, but this can to some extent be compensated by tone modification at the amplifying station if the values used are kept strictly standard.

Interior Wiring at Receiving End.

Interior wiring of the subscriber's pre-

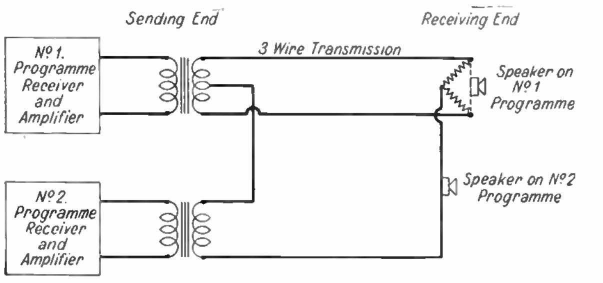

Fig. 4.—SENDING AND RECEIVING ENDS OF THREE-WIRE SYSTEM, FOR RELAYING TWO PROGRAMMES.

No. 1 programme is arranged across two of the wires. The alternative programme is transmitted by the third line. The first and second lines are at equal potential so no interference with No. 1 programme takes place.

mises from the protectors may be carried out in a good quality bell wire, the most popular for this purpose being constructed in a similar manner to cab-tyre lighting cables, but not so heavily insulated. In addition to saving on the initial cost of wiring, this wire being less obtrusive gives greater satisfaction to the subscriber.

A Warning About the Loudspeaker Adaptor.

Under regulations imposed by local authorities, which are now almost universal, the loudspeaker adaptor must not fit any standard electric lighting or power socket, the idea being to prevent people from accidentally connecting the loudspeaker to the electricity supply.

Wiring Points in Several Rooms.

Many subscribers have their houses wired with relay points in several rooms. In the case of single programme, these points are usually looped from room to room and may, if desired, be fitted with separate fuses. In dual programme systems it is considered advisable to have one master programme selector for the whole of the subscriber's premises and a single pair of wires from point to point.

Leading-in Wires for Dual or Multi-Programme Service.

For leading-in dual or multi-programme service, lead covered multi-core cables are usually employed, the separate pairs of conductors in these cables being screened from each other by tinfoil or metallised paper, these screens being bonded to the lead covering, which in turn should be earthed. To efficiently connect a multi-core cable to the lines a weather-proof joint box attached to the bracket is advisable. In addition to this a gauge of wire should be used for the actual connection similar to that of the line wire, whilst a finer gauge is quite satisfactory for the lead-in and internal wiring.

The internal wiring of a two-pair service may be carried out by screened conductors, but in practice it is found cheaper and quite as efficient to run two pairs of bell wire, one pair being of the side-by-side construction and the other pair twisted

THE EQUIPMENT REQUIRED AT THE SUBSCRIBER'S END.

All that is required by a subscriber of a low frequency service is a loudspeaker, a programme selector switch, and a volume control.

Potentiometer Volume Control.

The volume control is usually a 50,000-ohm wire-wound potentiometer, connected across the lines, the loudspeaker being connected between the slider and one side. Many suitable forms of these are available, the most desirable features being neatness, reliability and a logarithmic control.

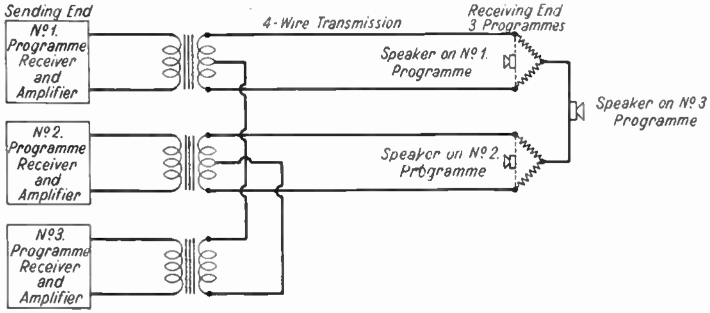

Fig. 5.—Sending and Receiving Ends of Four-wire System for Relaying Three Alternative Programmes.

No. 1 pair of lines act as one conductor and No. 2 pair as the other, the potential across each pair being equal in respect of No. 3 programme, whilst full signal voltages are imposed between one pair and the other.

Tapped Choke in Series with Loudspeaker for Control of Volume.

Another form of volume control introduced from Holland is the inclusion of a tapped choke in series with the loudspeaker. This method has been found to give more distortionless control than the resistance method

Volume Control by Moving-coil Speaker Tappings.

A more recent improvement is the use

of a moving-coil speaker with tappings to the secondary of the speech transformer, the tappings being taken to the selector. With the latter method it is possible to maintain the same tone irrespective of the volume.

The Choice of Loudspeakers for Radio Relay.

In choosing loudspeakers, it should be remembered that radio relay lines are in every sense of the word power lines, carrying a definite average A.C. voltage. The current consumption of a loudspeaker varies inversely as its impedance and careful study should be made of the curves of the instruments under consideration. Systems are in operation transmitting a mean single voltage as low as 20 volts, others operate round about 80 volts, and a loudspeaker which is suitable for the former would obviously not last very long on the latter system without a step-down transformer.

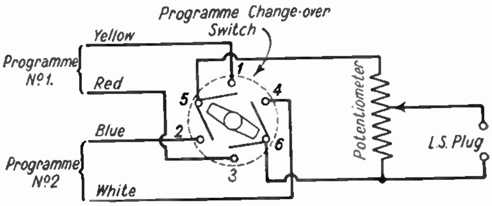

Fig. 7.—Circuit Diagram of Switch Panel at Subscriber's End of Low Frequency Radio Relay System.

As will be seen the panel is for a four-wire, two programme system. The actual equipment is illustrated in Fig. 6. Note that when the switch is turned for programme No. 1, contacts 1 and 5 and 3 and 6 are closed. For programme No. 2, the switch closes contacts 2 and 5 and 4 and 6.

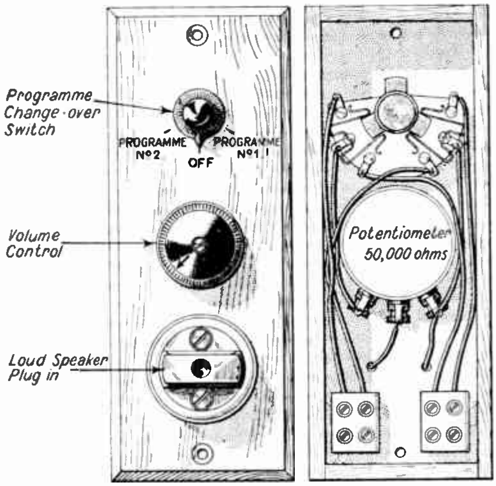

Fig. 6.—The Equipment at the Subscribers' End.

Showing the switch panel required by a subscriber of a low frequency four-wire, two programme service. Situated on the panel are the programme selector switch, a volume control knob and a socket to receive the loudspeaker plug. The picture on the right shows a view at the back of the panel and gives the wiring connections. The type of volume control employed here is a 50,000-ohm wire-wound potentiometer, connected across the lines, the loudspeaker being connected between the slider and one side. A better view of the wiring can be seen in the circuit diagram, Fig. 7.

Selection of Loudspeakers by D.C. Resistance

A common method of selecting loudspeakers is by the D.C. resistance; this may be a rough guide to the impedance of the ordinary magnetic types, but in the case of inductors and transformer-coupled moving-coil speakers is not reliable, the ratio between the D.C. resistance and impedance varying considerably when different types are being considered. The current consumption of a loudspeaker is an important feature to the relay operator, and a strict minimum to the impedance of the loudspeaker connected to the service is usually maintained; however, in the case of clubs and public places where more volume is required, the power on the lines being more or less unlimited, all that is necessary is a larger speaker with a lower impedance.

A Suitable Type to Use.

The most suitable form of speaker appears to be a narrow gap permanent magnet, moving coil, with a speech coil giving an impedance of 4,000 or 5,000 ohms. A relay service using this type of speaker only will give amazingly good results, but difficulty is experienced in matching this type of loudspeaker and moving-iron types to the same lines. There is little doubt, however, that eventually this type of loudspeaker will become universal on radio relay systems.

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PRACTICAL NOTES ON REGULATIONS FOR THE ELECTRICAL EQUIPMENT OF BUILDINGS (I.E.E. WIRING RULES)

By D. Winton Thorpe, A.M.I.E.E.

SUB-DIVISION OF CIRCUITS AND EARTHING

REGULATION 95, entitled "Sub-division of Circuits" is very important and its application is felt in practically every wiring job. It states—

A.—*The maximum number of points that may be connected in parallel to a final sub-circuit shall be as follows :—*

Where the total rating of the points supplied from the sub-circuit does not exceed—

6 *amperes*	..	10 *points*
8 ,,	..	6 ,,
10 ,,	..	4 ,,
20 ,,		2 ,,

Final sub-circuits supplying one lamp or appliance are not limited as to current-carrying capacity.

There is a note to the effect that—

In applying this Regulation it should be observed that when the fusing current of the fuse controlling a final sub-circuit exceeds 7 amperes the smallest cable or flexible cord which is used for any purpose on such circuit must be capable of carrying continuously a current not less than one-half of such fusing current.

Let us consider the case of a wiring installation for electric fires. If the voltage of supply is 200, a 3 kW. fire will be taking 15 amperes. Therefore it is contrary to this particular regulation to have more than one electric fire point on any final sub-circuit. It is as well to bear in mind that even if we know that the customer intends to use, let us say, 2-kW. fires, having a consumption of only 10 amperes, it is difficult to justify putting two points on one final sub-circuit in parallel, owing to the fact that though we may leave the customer armed with 2-kW. fires, it is the easiest thing in the world for that customer to decide that the fires are not hot enough and to go out and buy across the counter of any general store 3-kW. fires, which he or she will proceed to connect to our two points in parallel, thus immediately breaking Regulation 95A. In general, a fair interpretation is to refrain from ever connecting two heating points in parallel on one final sub-circuit.

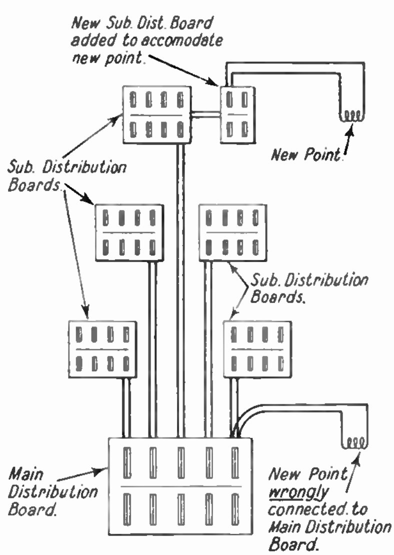

Fig. 1.—Right and Wrong Connections for a New Point. (Regulation 95B.)

The new point should not be connected direct to the main distribution board. An extra sub-distribution board must be fitted as shown, to which the new final sub-circuit is connected.

Where Final Sub-circuit must be Connected.

Subsection B of this Regulation states—

Every final sub-circuit shall be connected to a sub-distribution board.

That appears to be an obvious Regulation, yet once again, it is a Regulation which is defied on many occasions, chiefly where new wiring work is being added to an existing installation. If the sub-distribution board, supplying the final sub-circuit, is full up and has no spare ways and no spare current-carrying capacity on any existing way, there is undoubtedly a temptation sometimes to run back direct to the main distribution board. This must not be done. Instead, an extra sub-distribution board must be fitted, however small, which is served from the main distribution board. This extra sub-distribution board, in turn, serves the added sub-circuit or sub-circuits.

Connections of Distribution Board.

Section C of the same Regulation states—

Every sub-distribution board shall be connected to a separate way on a main distribution board. Each main distribution board shall in turn be connected either to a separate way on the main switchboard, or to one way of a distribution board for larger currents, which in turn shall be connected to the main switchboard, or to one way of a distribution board for still larger currents.

This is, in effect, merely carrying the idea contained in Subsection B a little further. It needs no further comment.

EARTHING.

Now we come to what is probably the most important, certainly the most interesting, section of the Regulations—that which refers to Earthing; this part of the Regulations is comparatively brief and includes Regulations 96 to 103. But for all their brevity they cannot be too heavily stressed.

Conditions Where Earthing is Necessary.

Regulation 96, entitled "Conditions Where Earthing is Necessary," states—

A.—*For all pressures of supply, earthing of metal objects other than the conductors shall be effected as follows:—*

(*a*) *In bathrooms, lift shafts, the immediate neighbourhood of running machinery, and all places where even a slight shock might lead to serious accident, all exposed metal liable to become alive in the event of the insulation becoming defective shall be earthed.*

(*b*) *Where any metal liable to become alive in the event of the insulation becoming defective is so situated that there is risk of accidental contact between it and earthed metal, it shall either be protected against such accidental contact or be earthed.*

(*c*) *The metal sheathings of cables installed in accordance with Regulation 87 (Class M1 and Class M2) shall be earthed. (That is all cables having a metal sheath, whether conduit or lead.)*

B.—*Where the pressure at the point at which the supply is delivered exceeds 30 volts in the case of alternating current, and 100 volts in the case of direct current.—*

(*a*) *If the conditions are such that a person touching any metal liable to become alive in the event of the insulation becoming defective is likely to be simultaneously making contact with earth, such metal shall be earthed.*

(*b*) *All metal conduits installed in accordance with Regulation 87 (Class T1 and Class T2) shall be earthed as near as conveniently possible to the point of entry of the supply, but isolated lengths of metal conduit need not be earthed except in the conditions specified in A (a) and (b) above.*

NOTE.—*A person is likely to be making contact with earth if standing on a floor which is conducting through damp or otherwise, also if in the immediate neighbourhood of masses of metal connected to earth, e.g. structural steelwork, gas stoves, water taps, etc.*

Where the metal cases of switches, distribution boards or other apparatus have to be earthed, special precautions should be taken to guard against the risk of shock or burning to anyone when working on live conductors in or adjacent to such apparatus.

Round this whole question of earthing there is much controversy. Some hold that earthing should always be carried out in every circumstance; others hold that earthing should not always be carried out in all circumstances. But whatever one's own technical views may be on the subject, it is as well to be perfectly sure of one's ground, or, alternatively, to adhere to the Regulations.

Earthing Metal Sheathing of Cables.

Taking this particular sub-section A in reverse order, (*c*) refers to the metal sheathing of cables. I suppose it would not be stretching a point to say that in fifty per cent. of private houses wired for

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electricity to-day it would be possible to find metal sheathing of cables, whether conduit or lead-covered, unearthed. I do not by this mean that it is common practice to connect no earthing wire from such metal sheathing to earth; it is rather that the earth wire carried in the scullery from some point on the conduit to a cold water pipe, is regarded by many wiremen as complete obedience to this subsection, whereas, in fact, the subsection is not satisfied unless every piece of conduit in the installation is connected to earth—not separately, of course, but by means of good continuity to the point which is connected to earth.

Exposed Metal Liable to Become Alive.

Subsections (*a*) and (*b*) of Section A leave a good deal of latitude in their interpretation, since the phrases "might lead to" and "liable to become" must remain largely a matter of opinion. My personal view in this matter is to regard any circumstances in which I could, even with an effort and quite deliberately, get a shock of any sort are circumstances which come within the provision of these two subsections. What the wireman must ask himself, if he is called upon to decide in a case of this sort, is, "here is the apparatus, here is a piece of metal which is liable to become alive"—and, by the way, any piece of metal forming the case of any electrical apparatus must obviously be held to be liable to become alive—"Is there within reach of my hand or my foot any other piece of metal already connected with earth, or any stone floor, or any moist conducting surface such that I can possibly span the distance between the piece of apparatus and this earthed contact? If there is, then I must earth the metal on my apparatus." Again, if, owing to such circumstances, the metal frame of a piece of electrical apparatus has been earthed, it must be remembered that this in turn now constitutes an earth and may necessitate the earthing of the metal on another piece of apparatus which was previously out of reach of a substantial earth. As an instance of this, we may consider the case of a drawing-room with a heavy pile carpet and no metal hot-water radiators or other conducting substance connected with earth in which it would be reasonably safe to place an electric fire with its metal frame unearthed. Should that metal become alive there still remains no reasonable liability of shock from it. If, however, we bring into this room, say, an electric fan having its frame earthed by a 3-pin plug, then the unearthed frame of our electric fire becomes a potential source of danger, since we have now introduced into the room the means of getting a shock. A fair maxim, in such cases, is—"All or nothing earthed."

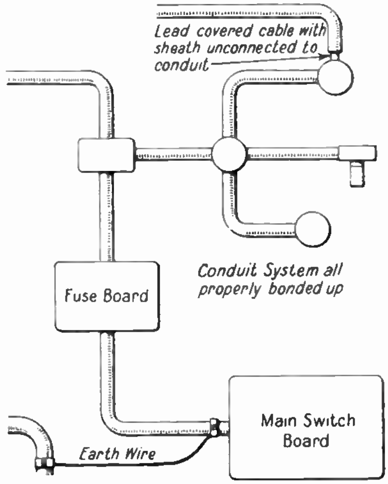

Fig. 2.—EXAMPLE OF A SYSTEM PROPERLY BONDED IN ALL BUT ONE SECTION (REGULATION 96c).

An addition of lead-covered cable with sheath unconnected to conduit contravenes the regulation.

Damp Plaster and Concrete.

Regulation 97 states:—

Damp plaster or damp concrete in contact with metal liable to become alive shall be considered, for the purposes of Regulation 96, to form part of such metal.

That is clear enough, but I would go further and suggest that all plaster and all concrete should be considered as damp plaster or damp concrete, inasmuch as it almost invariably offers a substantial conducting path to electricity. Plaster, in particular, will absorb a great deal of moisture from the atmosphere, to such an extent even that it can rarely be considered to be safe, so far as its connection with earth is concerned.

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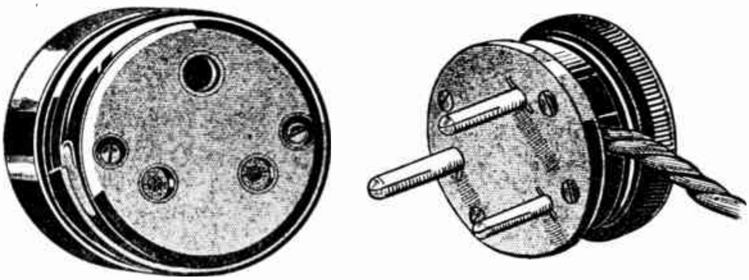

Fig. 2A.—A Three-pin Plug and Socket for Proper Earthing of Appliances.

The centre terminal of the socket is connected to any convenient earth, whilst the centre pin of the plug is connected to the metal casing of the appliance by means of a third wire plaited in the flexible cable as shown in Fig. 3.

Joints in Metallic Conduits and Sheathings.

Regulation 98 is entitled "Joints in Metallic Conduits and Sheathings," and reads :—

When the metallic conduits or sheathings of cables have to be earthed, or are themselves used as earthing connections, every joint in such conduit or sheathing shall be so made that the current-carrying capacity of the joint shall not be less than that of the conduit or sheathing itself.

In an earlier article in this series, I referred to slip tubing without any continuity fitting as being disallowed by the Regulations. This type of conduit, which is unfortunately used a very great deal, is specifically condemned in a note under Regulation 87, subsection xxvii, and is further indirectly condemned by this present Regulation No. 98.

Additional Precautions in Bathrooms.

Regulation 100, entitled "Additional Precautions in Bathrooms," states—

A.—*In bathrooms all exposed metal liable to become alive in the event of the insulation becoming defective shall not only be earthed (see Regulation* 96A (a)) *but, in addition, if not forming part of an electrically heated geyser having all exposed metal in solid and continuous metallic connection with the cold-water supply main, be placed out of reach of a person standing in the bath.* (*Also see Regulation* 123H.)

B.—*Lampholders in bathrooms shall have their exposed metal parts efficiently earthed, or alternatively, all parts liable to be handled when replacing a lamp shall be constructed of insulating material.*

This is a fairly well-known and fairly well-disregarded Regulation. From time to time we see reports of fatal accidents due to persons in a bath using electric hair-driers or having an electric bowl fire on the edge of the bath, or in some way or another doing what we know perfectly well is asking for trouble but of which they, rather naturally since they are not electrical engineers, do not realise the danger. This particular Regulation has been drafted so that we who are, in a sense, responsible for the safety of our clients and customers from electric shock shall know just how far we may go in introducing electricity into a bathroom. Take some glaring examples which can be found in many bathrooms to-day infringing this Regulation. The first thing is the lighting point, which may be suspended as a pendant fitting from the ceiling in a small bathroom in such a way that anyone standing in the bath could quite easily touch the metal lampholder. Now this metal lampholder clearly comes into the category of "metal liable to become alive in the event of the insulation becoming defective." Moreover, although it may seem unlikely that anyone standing in a bath will want to touch the lampholder,

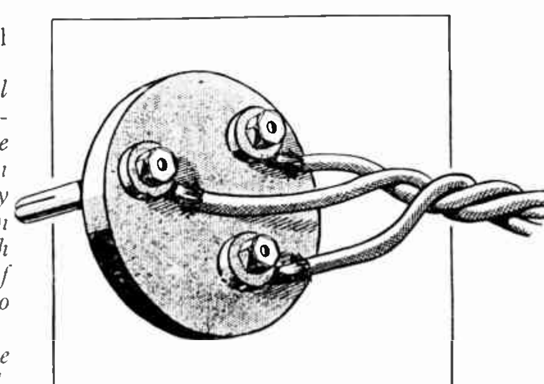

Fig. 3.—A Three-pin Plug Connection.
The centre wire has its other end joined to a metal part of the casing of the appliance.

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we must remember that a bath is always a slippery place and there is frequently a piece of soap upon which we are liable to tread. If we suddenly lose our balance, a natural instinct makes us stretch out a hand for any support which we can find; and this may be a pendant fitting hanging adjacent to a bath. Again, a switch within reach of the bath, if it is a metal switch, represents a piece of metal which is liable to become alive; therefore a switch within reach of the bath is contrary to the Regulations.

The Water Heater.

Reference to the water-heater, by the way, is merely to except the water-heater from this regulation for two good reasons. The first is that the water-heater, technically speaking, must go over and adjacent to the bath; and, secondly, that from its very construction it is in permanent connection with earth. An earth wire, however carefully we apply it, may get damaged or broken, and we can never be absolutely certain that a metal part which was originally earthed remains earthed. As this Regulation deals with a matter of life and death it is, therefore, not worth relying on an earth connection of this sort.

Precautions in Earthing.

Regulation 101—" Precautions in Earthing," brings us to the crux of the whole question of earthing, and should be followed implicitly where ordinary earthing methods are applied.

A.—*Great care shall be taken to secure as far as possible that the earthing system used shall be such that the combined resistance of the earthing lead and of the earthing system itself is low enough to permit the passage of the current necessary to operate the fuse or the earth leakage trip of the circuit breaker protecting the circuit.*

B.—*Water pipes used as an earthing system shall have metal to metal joints throughout.*

C.—*Pipes conveying gas or an inflammable liquid shall not be used as an earthing system.*

NOTE.—*The armouring of cables cannot in all cases be relied upon for the purpose of earthing.*

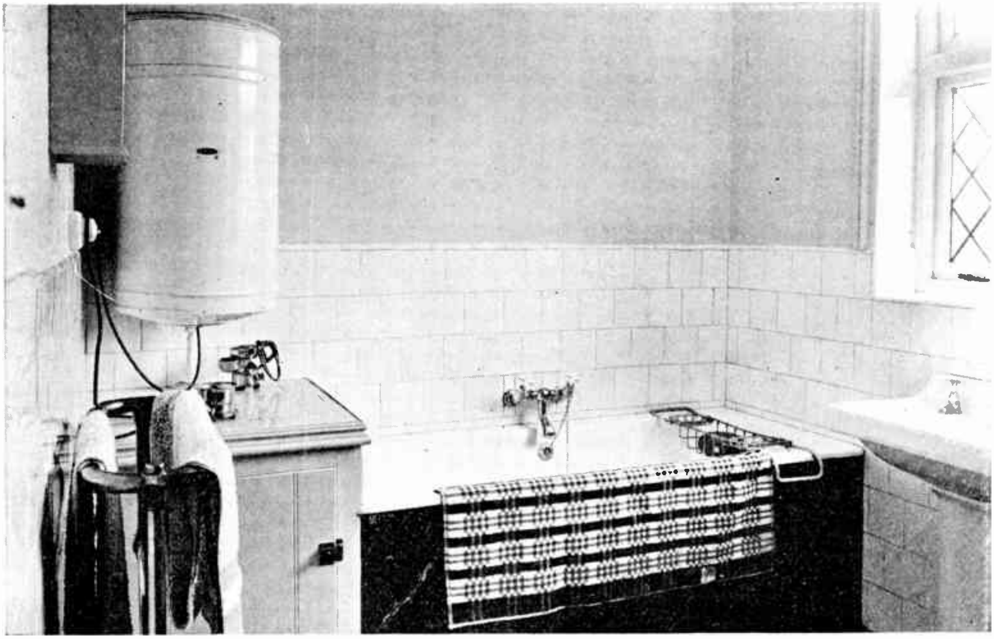

Fig. 4.—REGULATIONS FOR THE BATHROOM. (*E D A.*)
All exposed metal liable to become alive should be so placed as to be out of reach of anyone who may be standing in bath. The position of the electrically heated shaving outfit on the cupboard top contravenes this regulation. The water heater is, of course, naturally earthed.

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WATER HEATING BY ELECTRICITY

By J. RUSSELL HICKMOTT

Arrangements which are being pushed forward for running electric water heaters only at off-peak periods offer inducements to both supplier and consumer of electricity, and the ever-increasing use of electric heating may be anticipated. The article deals with the method of installation employed for both storage and immersion heaters

WATER heating by electricity has, during the last three years, developed to an almost unbelievable extent. It has brought with it numerous difficulties, both to supply engineers and those responsible for its installation. (By supply engineers I mean those who deal with the generation side of the question.)

Almost every supply company, to-day, loans out some form of water heating device. Although this raises difficulties for the supply company, it is agreed by all engineers that it has at least one redeeming feature which more than makes up for the time and trouble necessary in effecting a reliable and economical installation. This important feature is that the heaters can be arranged for off peak load, and is dealt with at the end of the article.

THE STORAGE HEATER.

General Features of This Type.

There are two essential types of water heating installations. The first, which is perhaps the simplest to install, is the self-contained storage heater. This consists usually of a cylindrical tank containing a heating element and a thermostat. The tank is surrounded by some insulating (heat) material such as cork, kept in place by a thin outer shell.

This outer case is enamelled and provides the apparatus with a very pleasing appearance. Figs. 1, 2 and 3 illustrate heaters of this type.

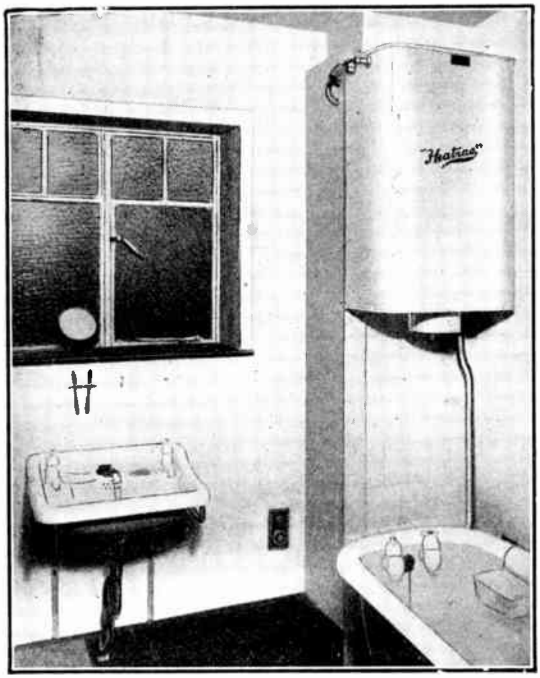

Fig. 1.—A CISTERN TYPE STORAGE HEATER INSTALLED IN A BATHROOM.

Fig. 2 shows the internal construction of this type of heater.

Method of Installation.

The majority of storage heaters are fixed above the point they are to supply, usually the bath or the sink. They may be connected with pipes to the ordinary hot water taps or if supply is only required at one position, the outlet on the heater will prove sufficient.

The Question of Working with an Existing System.

It is possible to arrange the storage heater to work in conjunction with the existing hot water

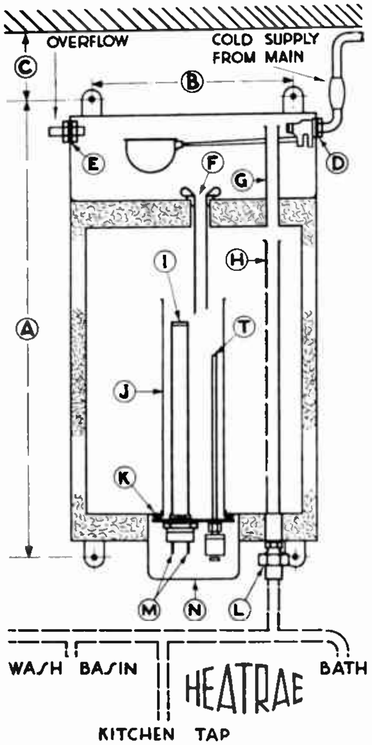

Fig. 2.—The Internal Arrangements of a Cistern Type Heater.

D and E, ball valve and overflow union positions are interchangeable; F, cold water feed to heating chamber; G, expansion pipe; H, hot water delivery pipe with graduated perforations; I, immersion heater; J, cylinder to retain water in case main water chamber empties; K, removable bottom plate for cleaning purposes; L, union connection for hot water supply piping; M, main terminals for supply cable; N, removable cover giving access to all electrical connections; T, thermostat.

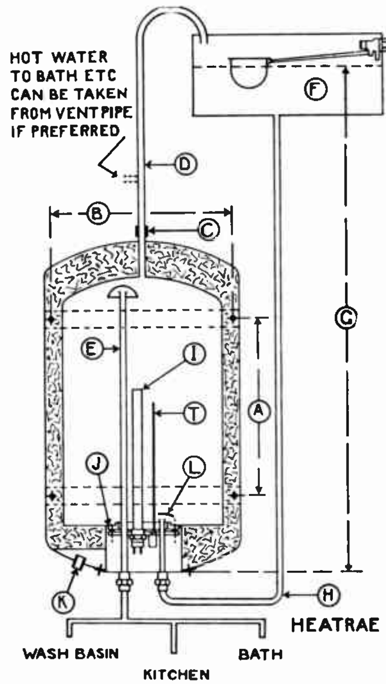

Fig. 3.—Pressure Type Storage Heater.

D, expansion pipe, from which tappings for hot water supply can be taken, if desired; E, additional hot water outlet; G, maximum head of water 40 ft.; H, cold water feed; I, immersion heater; J, removable bottom plate for cleaning purposes; K, cable inlet bush; T, thermostat.

system, but usually it is found to be considerably cheaper to use immersion heaters in a conversion job. I have, therefore, dealt at some length with this type of heater.

THE IMMERSION HEATER.

The use of immersion

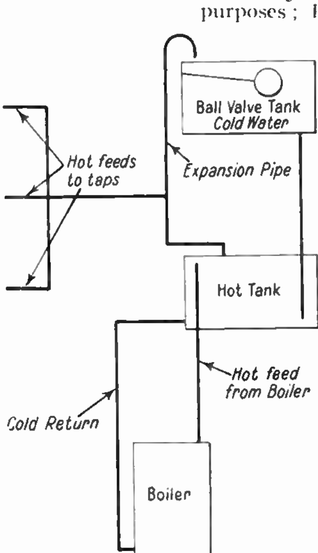

Fig. 4.—This shows the Correct Arrangement of Existing Piping for Converting Boiler System to Electric Heating.

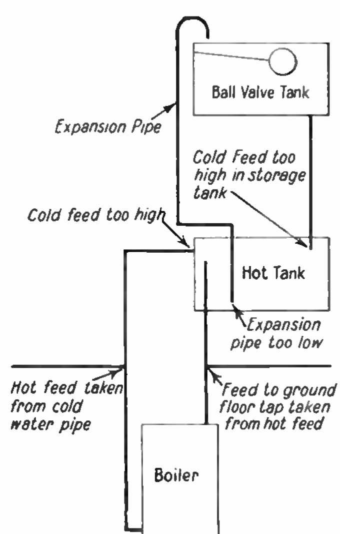

Fig. 4a.—Common Faults Found in Hot Water Installations.

heaters provides a highly efficient method of heating water for domestic purposes. Although great care has to be exercised in their installation they are remarkably simple to install.

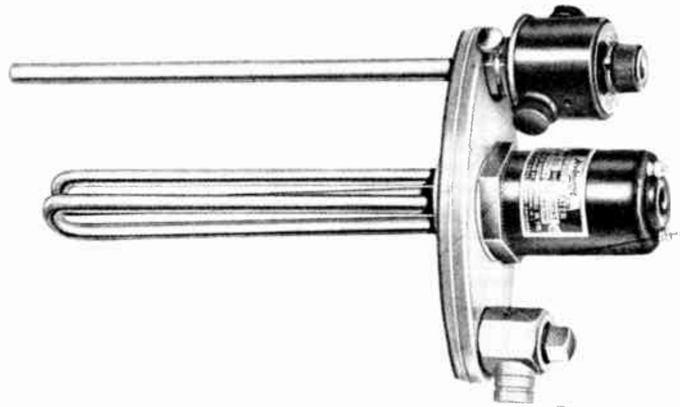

Fig. 5.—HOTPOINT IMMERSION HEATER AND THERMOSTAT MOUNTED ON FLANGE READY FOR INSERTION IN HOT WATER TANK.

How to Convert an Existing Hot Water System.

The usual method of installation is as follows:—

Almost every house has a hot water system worked from a coal or coke fired boiler. A hot water tank being provided usually in the linen cupboard or the kitchen in a more or less accessible position. The sizes of the tanks vary, but a 25/30 gallon is the most common. If the size is below this, the idea of conversion should be abandoned owing to the low storage capacity.

Fitting Heater and Thermostat to Tank.

Into the hot water tank is fitted, about three inches from the bottom in a horizontal position, the immersion heater. About three inches above this, but staggered to one side, is fixed the thermostat which is wired in series with the heater.

Insulating the Tank.

The tank is then lagged by building around it a wooden box about four inches from the tank. The space thus obtained is filled with some heat insulating material such as asbestos or granulated cork.

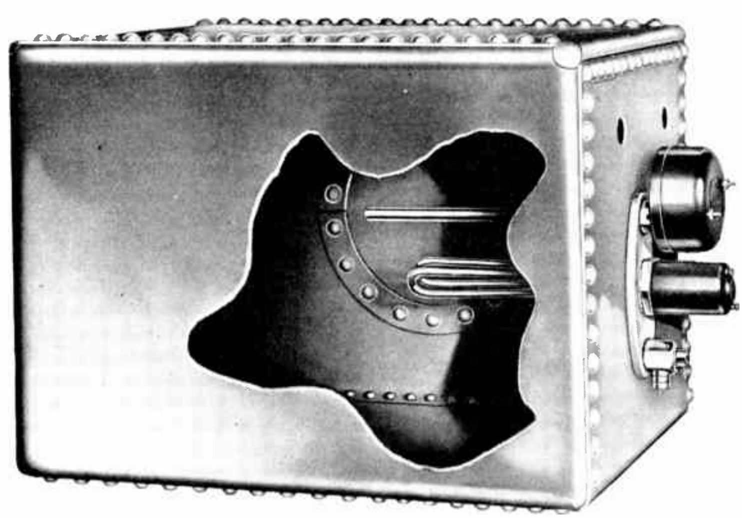

Fig. 6.—A HOTPOINT IMMERSION HEATER AND THERMOSTAT COMPLETE WITH FLANGE FITTED TO STANDARD HOT WATER TANK OF EXISTING SYSTEM.

Correct Arrangement of Piping for a Conversion Job.

Before commencing an immersion heater job, the existing piping should be carefully examined. In Fig. 4 the correct piping work is shown. Fig. 4A gives some of the more common faults which are to be found in hot water installations. If any of these faults are

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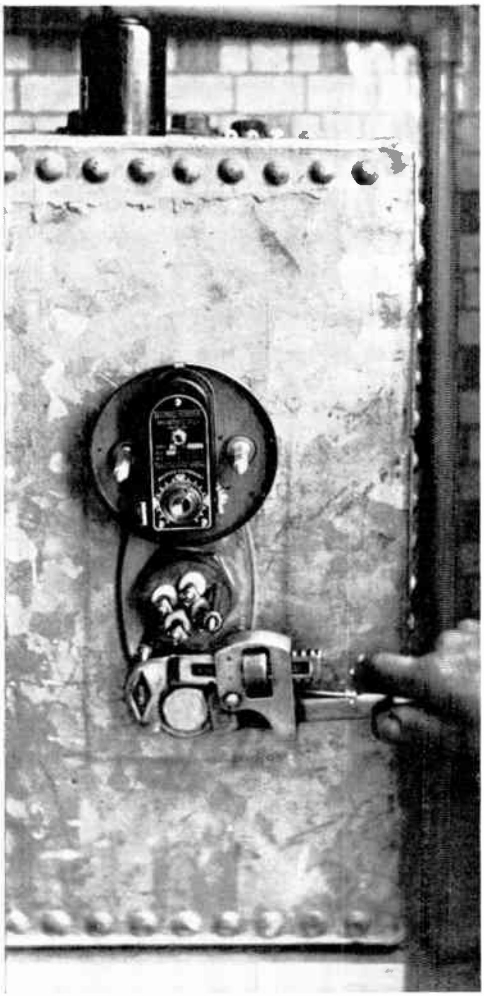

Fig. 7.—Final Fixing of Flange, Complete with Immersion Heater and Thermostat, To Hot Water Tank.

Fig. 8.—Wiring Connections Being Made To Thermostat.

discovered they should be rectified or the job refused.

SIMPLE CALCULATIONS.

Some elementary calculations are necessary if running costs, etc., are to be produced. The following figures and formulæ are approximate and should not be taken as laws. At the same time they are correct enough for most practical purposes:

Water Temperatures.

Cold water	40 to 50 degrees F.
Bath water temperature	100 to 110 degrees F.
Dish washing	125 degrees F.
Scalding	150 degrees F.
Boiling	212 degrees F.

Tank Capacities.

Rectangular tank—

$$\frac{\text{height} \times \text{width} \times \text{depth}}{276} \text{ gallons.}$$

Cylindrical tank—

$$\frac{\text{dia.} \times \text{dia.} \times .78 \times \text{depth}}{276} \text{ gallons.}$$

All the above measurements are in inches.

Fig. 9.—FINAL CONNECTIONS BEING MADE TO IMMERSION HEATER, SHOWING ALSO WOOD BOX ROUND TANK CONTAINING LAGGING.

Consumption of Water Heaters.		Units per Week.
Self-contained storage type ..	20 galls.	70/100
Immersion heater	25 galls.	60/80

Heating Formulæ.

Kw's required—

$$\frac{\text{galls.} \times \text{temperature rise degrees F.}}{\text{time in hours} \times 341 \times \text{efficiency \%}}$$

If an efficiency of 88% is taken the above cancels out and we have :—

Kw's required—

$$\frac{\text{galls.} \times \text{temperature rise degrees F.}}{\text{time in hours} \times 300}$$

Storage Heaters Arranged for Off Peak Load.

One of the most important facts in regard to water heaters is that they can easily be arranged to be on circuit only during the off peak periods. In fact a number of supply authorities and companies make a specially low charge for current consumed under such circumstances. If a water heater is to be arranged for off peak certain precautions must be taken to ensure that there will be sufficient hot water for use during the day.

The maximum quantity of hot water likely to be required should be ascertained and a storage heater of sufficient size installed. A special type of heater is made for this purpose having a device that automatically closes a valve in the cold water feed when the current is switched off and opens it again when the current is switched on. The current is controlled, of course, by the usual time switch.

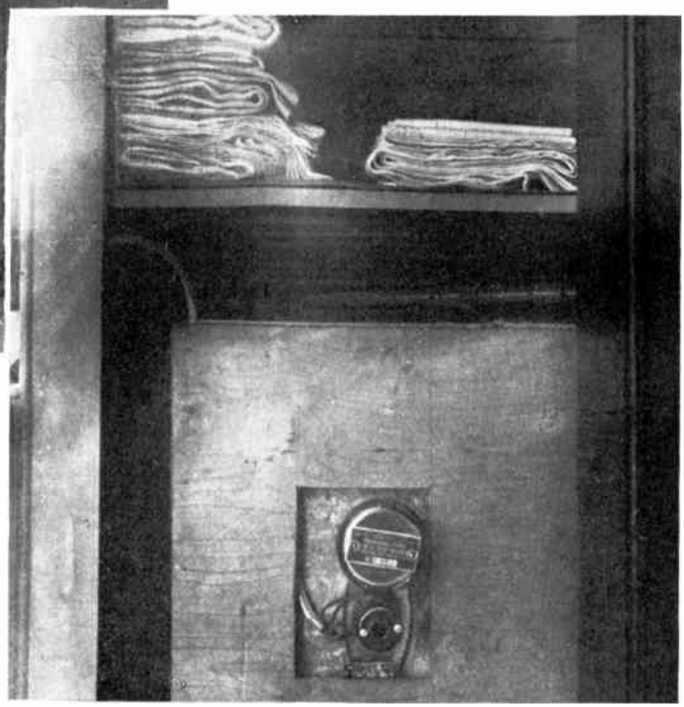

Fig. 10.—THE COMPLETE INSTALLATION.
The hole left in wood cover allows escape of sufficient heat to air clothes in cupboard above.

The arrangement of water heaters on off peak has proved to be of such enormous value to supply authorities that the scheme is being pushed to its fullest extent in all enterprising districts.

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MERCURY SWITCHES AND THEIR APPLICATIONS

By "VOLTUS"

THE mercury switch offers a number of distinct advantages over the electro-magnetic relay described by Mr. Butler in the June issue of the PRACTICAL ELECTRICAL ENGINEER.

Breaking Capacity of the Mercury Switch.

These switches are capable of breaking 50 amps. at 230 volts D.C., while small currents at pressures up to 10,000 volts can safely be dealt with. An electro-magnetic relay equipped with solid contacts will not break more than 1 ampere without excessive sparking. The electrically operated magnetic contact of 50-amp. capacity has a bulk far greater than the equivalent mercury switch with the added disadvantage of open sparking and consequent rapid contact wear.

Absence of Open Sparking.

These switches with their total enclosure and consequent absence of open sparking are invaluable in locations where inflammable gases and vapours are present, such as mines, petrol pumping plants, etc.

A further advantage is the very small force, applied electrically or mechanically, required to tilt the switch unit.

Average Life of Switch.

The contact efficiency is unaffected by repeated operation under full load. Life tests carried out to destruction indicate the following average life for varying currents.

Breaking 4 amps. at 110 volts—1,000,000 operations.

Breaking 6 amps. at 110 volts—200,000 operations.

Breaking 12 amps. at 110 volts—50,000 operations.

The replacement cost of the switch unit varies from 3s. to £2 in the largest sizes. This compares very favourably with the cost of contact replacement and maintenance of other types of relays and contactors.

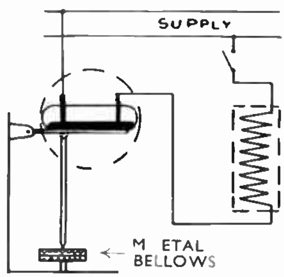

Fig. 1.—THERMOSTATIC CONTROL OF HEATER.

As shown, the mercury switch is in the closed position, and the heater is in circuit with the supply. The temperature rises and expands the volatile liquid contained in the metal bellows. The bellows expands and tilts the mercury glass, thus breaking the circuit.

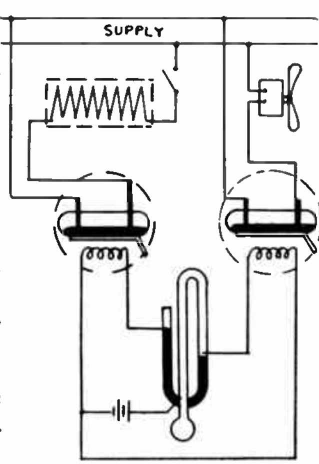

Fig. 2.—TEMPERATURE CONTROL BY HEATER AND FAN.

In this example, the operation of heater and fan switches is controlled by a maximum and minimum thermometer.

APPLICATIONS.

The typical examples following are intended to illustrate the wide scope of application for these switches.

Thermostatic Control of Heater.

As previously mentioned, very little energy is required to tilt the mercury unit and this enables a relay to be constructed wherein the expansion and contraction of a metal bellows filled with a volatile liquid provides the operating force. The relay construction is diagrammatically shown in Fig. 1, together with the heater connections.

Temperature Control by Heater and Fan.

This is an elaboration of the previous example, control being provided for both heater and the fan (see Fig. 2).

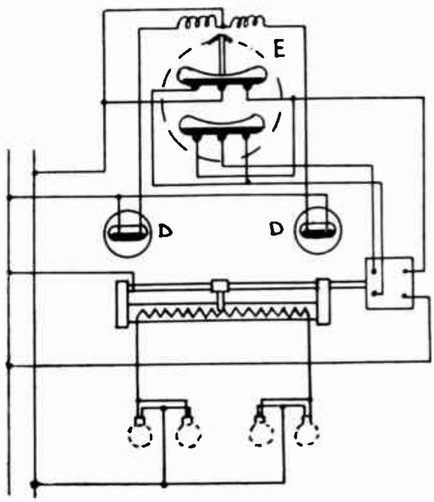

Fig. 3.—CONTINUOUSLY OPERATED COLOUR LIGHTING DIMMER.
A limit switch, D, is provided at each end of the slider travel. This switch operates a polarised relay, E, which reverses the driving motor each time the end of travel is reached.

A maximum and minimum thermometer provides the master control. Contacts are incorporated in the tube walls and the rise and fall of the mercury makes or breaks the circuit. Increase in temperature will cause the right-hand level to rise and open the heater switch, at the same time the left-hand level falls, closing the fan switch. A suitable allowance of overlap is provided for the contacts to prevent the fan starting immediately the heater is cut out.

Extremely fine control is possible, due to the form of master control provided.

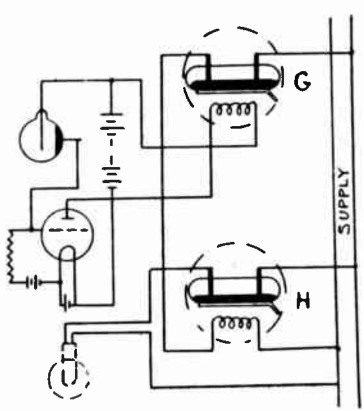

Fig. 4.—AUTOMATIC LIGHT CONTROL.
Here the master control of the mercury switches is provided by a photo-electric cell in conjunction with a valve amplifier. When the light falls below a certain value, the control current given by the amplifier operates a special sensitive relay G. The closing of this switch energises the operating coil of the switch H, direct from the mains.

Continuously Operated Colour Lighting Dimmer.

This circuit (Fig. 3) controls a colour-lighting installation of two banks of lamps of different colours. The cycle of operation is as follows. One set of lamps gradually attains full brilliance, while the second set is faded out, the latter set then gradually comes into use while the first colour then fades out.

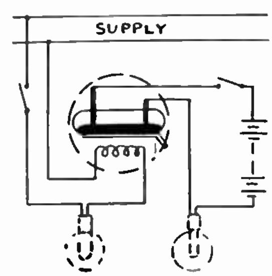

Fig. 5.—AUTOMATIC EMERGENCY LIGHTING SWITCH.
Mercury switch controlling emergency supply is held off by coil which is energised as long as main supply is available. Failure of this supply closes switch and brings second set of lamps into operation.

A limit switch, D, is provided at each end of the slider travel. This switch operates a polarised relay, E, which reverses the driving motor each time the end of travel is reached.

Automatic Lighting Control by Photo-electric Cell.

Here the lighting circuit is arranged to be switched on when daylight falls below a certain value. The master control is provided by the photo-electric cell in conjunction with a valve amplifier. The circuit is shown in Fig. 4.

The control current given by the amplifier operates a special sensitive relay, G. The closing of this relay energises the operating coil of the switch, H, direct from the mains.

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Automatic Changeover Switch.

In many locations an emergency alternative supply for the lighting is essential. A second main supply may be available or a battery of accumulators installed.

The switch controlling the emergency supply is held off by a coil which is energised as long as the main supply is available. Failure of the latter at once closes the switch (Fig. 5), bringing the second set of lamps into operation.

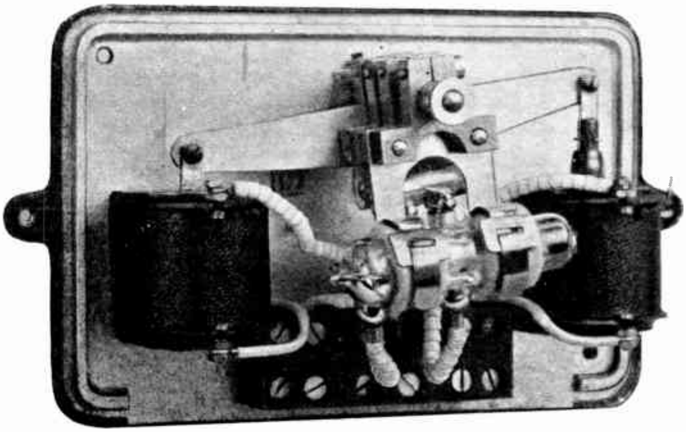
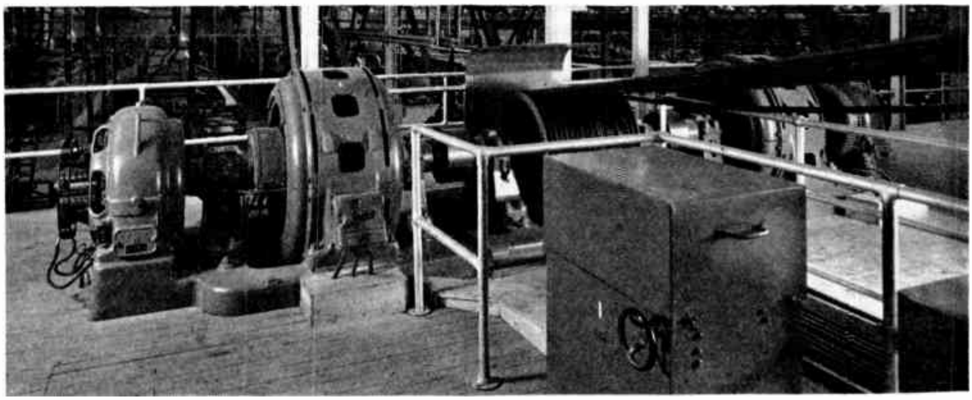


Fig. 6.—A Typical Example of a Mercury-type Relay.

A typical example of the mercury-type relay, made by Messrs. Isenthal, is shown in Fig. 6. The glass container for the contacts and mercury will clearly be seen.

AN INTERESTING APPLICATION OF SYNCHRONOUS MOTORS



The illustration shows the main drive for a number of the heavier machines in the new biscuit factory of Messrs. Macfarlane Lang & Co. Two 150 h.p. G.E.C. Witton synchronous induction motors are mechanically coupled together, and arranged so that each can run by itself driving the second machine idle, or the two can run in parallel. This drive is probably unique. These motors not only drive the main line shaft through a rope drive, but are also used to improve the power factor of the whole installation. The motors and control gear have been designed so that for any given setting of the regulator, they share the mechanical load and the power factor correction equally within 5 per cent. The load on these machines varies widely, being half its maximum value for long periods. At these times one motor can be run by itself on full load and the other driven idle, an arrangement that gives a higher overall efficiency than if one motor of double the size were installed and run for long periods at half load and therefore low efficiency.

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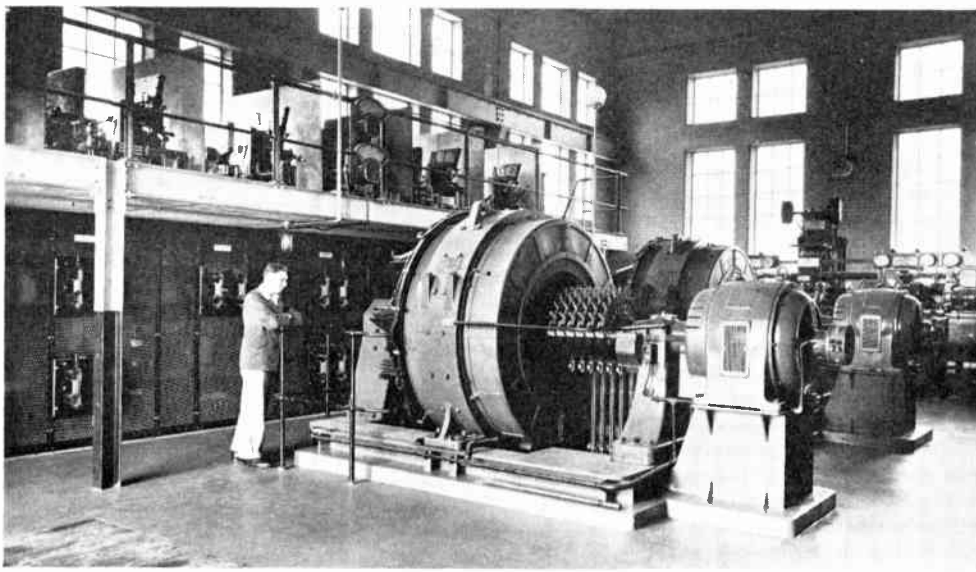
THE OPERATION OF CONVERTER SUBSTATIONS

By W. T. Wardale, A.M.I.E.E.

In this article, the author gives the benefit of his experience as head of a large traction system for many years. Mr. Wardale deals with the points to which particular attention must be paid by the man in charge. He describes how to avoid faults and how to deal with the mishaps which may occur



A General View of the Upminster Substation on the Barking Upminster Line of the L.M.S. Railway.

Showing B.T.H. rotary converters. These machines are shunt wound, each rated 1,200 kW., 600 r.p.m., 630 volts, 1,904 amps, and are equipped with starting motors arranged for series self synchronising. The machines are arranged for automatic operation and are provided with bearing thermostats, earth leakage relays, speed limit devices, and auxiliary shunt fields. The photograph shows the A.C. end of the machines.

WHILST modern converter substations are of the automatic type, yet many manually operated converting plants are retained at "key" positions, in order that certain of the automatic plants may be under supervisory control.

Intelligent and trustworthy service in such plants will fit a man for trial in such posts as supervisor of manual or automatic plants, or even out on the mains network.

Points to Watch.

Keen attention should be paid to the recording ammeters and voltmeters. Good handling of the machines and switchgear is expected; legible entering up of log readings and reports, and good timekeeping are essential. Circuit breakers which trip on fault or overload must be dealt with promptly and by no means missed through carelessness until someone rings up from outside to complain that the power is off. All these properties the substation man must possess, or he is no use whatever.

CONTROL OF VOLTAGE.

Importance of Keeping Voltage Correct.

Observe a strict control of the substation voltage. Keep to the voltage decided on by the super, especially when in parallel with other substations. Keeping too high a voltage will upset the distribution, will drop automatic substations out of service at an earlier hour than is desired, and lead to much reduced pressure on the network at the far end.

Make Notes of Any Alterations Required.

Should your observation suggest that any alteration is required in the pressure, make careful notes of load at various times, the coming on and going off of automatic substations working with your own, and especially of any long continued under or over loading of your plant.

Another serious objection to over pressure running, especially in traction substations, is that it overheats the machines and leads to early breakdown.

Damage Caused by Over Pressure Running.

All converters are built to work between certain well defined voltage limits; within those limits they work close to unity power factor. At unity power factor, all the current supplied to the A.C. portion of the converter produces a useful output on the D.C. side. When these voltage limits are exceeded in order to get higher pressures at certain points on the line, then the excitation of the machine has to be increased very considerably. This over excitation in turn tries to make the A.C. end of the converter supply back into the mains which are driving it. This being a physical impossibility, the tendency is corrected by the machine drawing a current from the A.C. line which leads the voltage considerably. This heavy leading current does no useful work, and provides no output on the D.C. side of the converter. It simply circulates round the A.C. windings of the machine and heats them up. It is for this reason termed wattless current or idle current.

Effect of Heating Up of the A.C. Coils.

This heating up of the A.C. coils perishes the insulation rapidly and in the case of the type of converter known as the motor converter, where pressure of 6,600 or 11,000 volts are taken straight on to the stator windings, it is exceedingly serious.

How Eddy Currents Are Set Up.

Not only are the coils carrying extra high tension current overheated seriously, but the iron laminations of the stator becomes so hot that the separating medium between them is soon destroyed; they come into contact at innumerable points, allow eddy currents to be set up through the stator iron and so again increase the overheating of the whole stator, besides impairing the working efficiency of the machine.

This overheating has been known to be so serious as to lead to the stator laminations moving and taking up nearly all the air gap between them and the rotor. When it is realised that any movement of this kind is nearly certain to start cutting into the insulation of the coils, the real seriousness of the damage which must follow over pressure running can be realised.

Tests taken by the writer on this point show that for a ten per cent. increase above the designed limit of voltage on such a converter, it was necessary to get 70 per cent. increase in excitation current.

Enter Emergency Conditions in Log.

If, during emergencies, it is necessary to run under such conditions, log the the fact, log the A.C. ammeter readings, the D.C. output, and the leading power factor the machine carries. If there is an ammeter in the field circuit also log the extra field current taken during that period, and call attention to the matter.

Testing Temperature of the Low Tension Cables.

The rotary converter is supplied with low tension A.C. current from a transformer. The low tension cables from the transformer to the slip rings should be encircled by the fingers three or four times each shift to check the temperature. Normally, they will be just above chill

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point; now and again, however, one or other will show a higher temperature. Mark this cable and watch it. An increase in temperature will show that there is a bad contact somewhere between the cable and its terminals, either at the transformer or the slip ring end. Get the converter off load as soon as possible, and then let the super know of the matter immediately. If not detected such a fault might burn out the cable concerned, or cause trouble in the transformer or at the slip rings.

SYNCHRONISING.

Whether your converters are of the modern type fitted with automatic synchronising gear, or whether they depend on the skill of the man in charge, always take time over the synchronising operation. At the best, flying shots can only save seconds, and may, if they miss, waste many minutes. Whatever the emergency, it has happened, and things are carrying on. Quick synchronising is necessary, certainly; but it is always attained by steady and deliberate action.

Switching in on the A.C. Side.

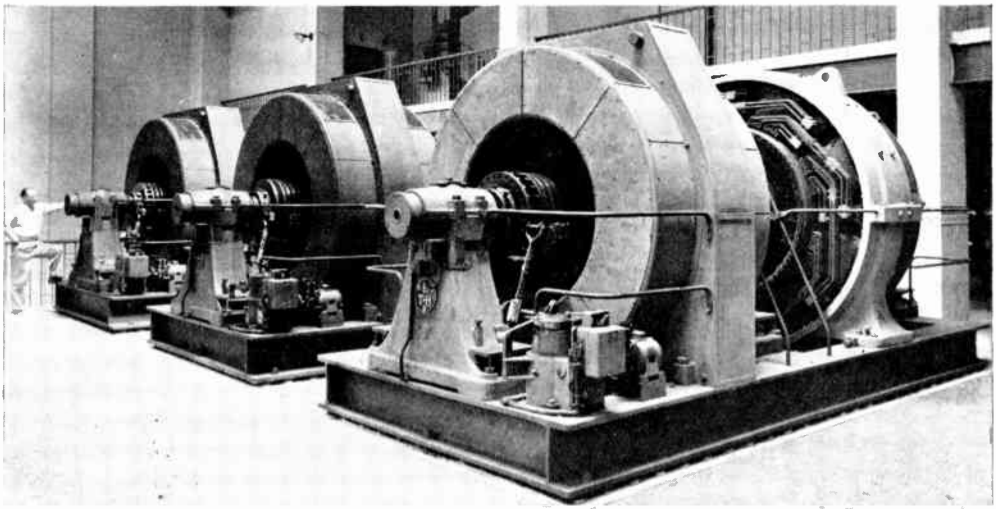
Set the rheostat in the correct position, run up and wait for the sound which you know from experience to be the point at which the machine closes easily, and then take the first good phase which comes up.

When to Close the Positive Switch.

When in on the A.C. side, wipe over the commutator, see your field is right, get the equaliser and circuit breaker in, and then close the positive switch with the machine volts about two volts higher than the bar, *but dead steady*. That is, not with a *rising* machine voltage. Otherwise a kick right over may bring you out again; and in any case you get a bad jerk on the converter and system.

Steady and Deliberate Action is the Quickest Under All Conditions.

If the man at another sub is shouting for help, the above method is the quickest way to help him. He is carrying on, and even 200 amps. taken by your machine will ease him a little, and you can then



A Modern Motor-Converter Substation.

The three B.T.H. motor-converters shown are installed in the Arlington Road substation of the St. Pancras Borough Council, and are each designed for a normal full load output of 2,500 kW., 450/510 volts, 5208/4901 amperes when supplied at 5,000/5,300 volts, 3 phase, 50 cycles. They will give overloads of 25 per cent. for two hours or 50 per cent. for 15 minutes, following a full load run and will deliver twice full-load current for 15 seconds.

take a look round your own machine, see it is all in order and then work full load on in a few minutes.

Even in a bad crisis when some circuits have had to be cut out momentarily, the steady course is the quickest as well as the safest.

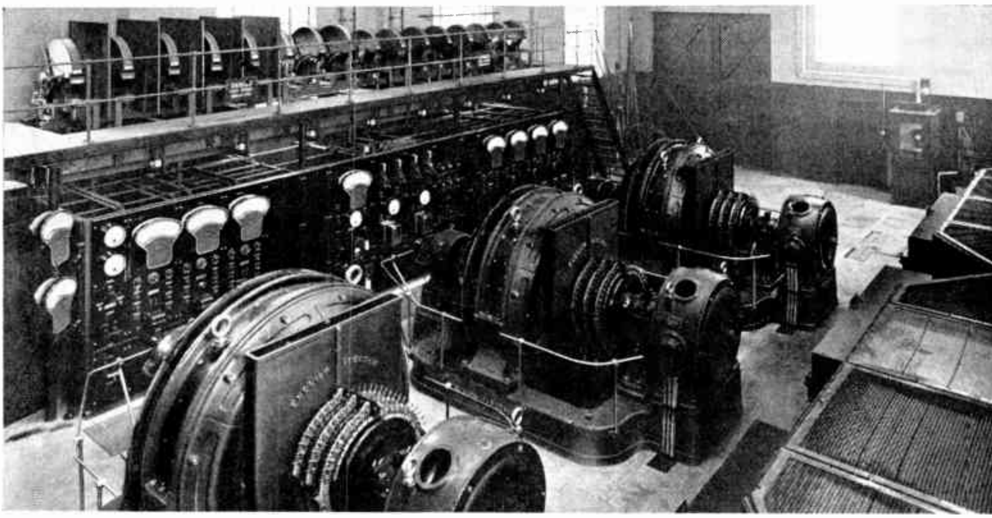
There have been cases in which men have been injured badly and the machine damaged whilst running up in panic haste. Field switches have been pulled in mistake on such occasions, resulting in burnt out armatures. Field switches which can be made and unmade are an abomination which, personally, I always abolish by having them bolted in. Wrong polarity can be corrected by a shut down and restart with safety, if with a little delay. But it is at least safer than the risk of opening a field switch by mistake.

Testing Your Tripping Devices.

Test all your tripping devices frequently, particularly the reverse cut-out and the A.C. protection. The latter by always tripping the machine on the A.C. side from the push button on the d.c. board.

Attention to Machine.

Renew brushes as soon as they show signs of undue wear. Note the temperature of commutator and slip rings frequently and of the pole pieces on the field. Keep the rheostat contacts well cleaned and the slider working freely. Cleaning the machine not only keeps a smart appearance, but is primarily for the purpose of getting dirt out of dangerous places, and the equally important matter of observing every part of the machine intimately, and so noting any portion which is becoming abnormal, or shaping to develop trouble.



A MODERN 3,600 KW. AUTOMATIC SUBSTATION FOR COMPLETE SUPERVISORY CONTROL ON THE LONDON, MIDLAND AND SCOTTISH RAILWAY SYSTEM.

A signal from the supervisory point energises a relay in one of the cabinets (on the right) controlling the machine selected. This closes the E.H.T. switch and puts L.T. A.C. on to the starting motor on the right of the rotary. Other relays bring rotary to synchronous speed, close the field circuit, which is supplied by the exciter on the left-hand end of the rotary, and after a definite time delay, switch the machine into the bus bars to supply the system. The circuit breakers are on the gallery. Other devices protect the machine against faults, overloads, hot bearings, or shut the set down if it is not on load within two minutes from starting up; or if the load on the section becomes too light for the machine. (*The English Electric Co., Ltd.*)

THE FEEDERS.

The Meaning of Sudden Jumps.

Occasional heavy kicks on a machine or a feeder are of little significance if they rise and fall with a fairly steady swing. A sharp sudden stab may indicate a consumer's appliance which has got across the system and been burnt clear, or a collector shoe or bow on a traction system which has fouled and swung clear again.

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A Sudden Swerve Down of Voltage.

A sudden swerve down of voltage accompanied by screaming from the converters indicates a surge on the A.C. side, caused by a serious mishap somewhere which has burnt clear, or been cut out by the protective gear.

What to do When a Surge Pulls a Machine Out.

Should such a surge pull a machine out for you, act as follows. If after peak time, swing as much of your load as possible over to the next sub-station which is working in parallel with you, and then get the tripped machine in again after a glance round to see that all is in order.

If during peak time, however, and your remaining machine threatens to come out on overload, trip your two least important feeders in order to save the rest, ring up any station which can help you and ask for assistance, and having arranged for help close the two tripped circuits and set to work to find out what is the matter with the machine.

Assistance From Other Sub-Stations.

Should the machine be flashed over, tell the man at the other sub-station that you are partially disabled and that he will have to hang on to some amount of overload for an hour or more. He will then make the necessary arrangements to spread his supply where possible. Should you be appealed to in a similar case, do all you can to help, remembering that any decent machine will stand 25 per cent. overload for two hours on end. If you are in charge of a supervisory sub, having distant control over a semi-automatic plant, then make that plant take its overload to ease you a little and permit you to give all help possible to the man who is broken down.

Putting Flashed-over Machine Back Into Service.

The man in charge of the flashed-over machine should let the super know immediately, and then set to work to clean up the commutator and brush gear and see if there is any worse damage, and get a megger test on the plant. By that time the super will be in, and will take charge of trying the machine again. It is not advisable for a sub-station attendant to put a machine on load again after such a happening unless the case is serious; that is unless circuits are out and waiting. If possible, let the super see the test and look round the machine before trying it on load. Watch his methods—the manner in which he looks round to see all is clear, the tests he makes and the manner in which he runs up.

Method of Testing the Machine for Defects.

Personally, I like to run up to half voltage, and then trip the machine, take another look round and another megger test. This start up and interruption give a slight kick to the machine and its transformer, above working voltage, and will bring out any slight defect lying hidden, and trip the machine before it reaches a dangerous voltage or speed; or, show by a much lower megger test that something is happening internally and that caution is necessary.

As a rule, however, the run up goes through as a matter of course, the machine is synchronised and left running light for ten minutes whilst its voltage is gradually worked up to full value. It can then be put into service on the d.c. side with confidence.

What to do in Serious Emergencies.

During serious emergencies the above tests must be reduced to a matter of solitary minutes, first at half and then at full voltage; it is on this account that the advice is given to let the super run up first. His longer experience and knowledge of many machines give him an intuition as to whether the machine is right or not, by the manner in which it comes up and the sound it makes in running up to speed. It is this experience which makes the super apparently take risks with an easy mind during such emergencies.

Note all such happenings carefully and the exact time by the sub-station clock.

TROUBLE ON 3-WIRE D.C. SYSTEM.

Service Gone to Earth.

Sometimes on a 3-wire D.C. system, the voltmeter on one side will come down once

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or twice almost to zero and then stay at normal. Probably a service has gone to earth and burnt clear. If fortunate, you may also have noted the feeder ammeter most affected. You can then ring up the mains stand by man to warn him of trouble of a minor character on that feeder.

Above all on a 3-wire D.C. system, note the out of balance which occurs just as the peak is mounting up, and also as it is dropping off ; at both times this out of balance current is apt to be heavy, and it always fluctuates very rapidly during such heavy load charges.

Note the voltages shown by the pilot wires which show the pressure at the far end of each feeder. If you find that the central load is sufficiently heavy to require the sub-station voltage increasing a little, but that the pressure at lightly loaded distant points is too high, it is possible to correct the matter on a ring connected network by dropping out the feeder supplying a distant point, and then increasing the voltage on the sub-station bars. This gives the central supply its extra pressure, and by feeding the distant point through the ring and not directly through its own feeder actually brings the pressure at the lightly-loaded distant point down to normal. This can usually be done without overloading the central feeders as the lightly-loaded distant point is supplied through all other feeders which are connected to the ring network, and not through one feed only. Keep the earth indicator chart clean, and report any indications.

FAULTS ON A TRACTION SUPPLY.

On a traction supply it is necessary to distinguish between motor faults, dead shorts, and cable faults developing.

Vehicle Motor Faults.

A motor or controller partially to earth, or with an earthed point on it, will blow the circuit breaker sharply; on its being reclosed, the load will take one or two fitful sweeps in an upward direction, and finally the ammeter needle will go right over and the breaker open again when the faulty portion is reached.

Allow the Faulty Vehicle to Clear the Line. Inform Traffic Control Staff.

With such a fault it is not possible to keep the line dead as a rule. It is best to allow the faulty vehicle to try to limp to a siding, or, if it blows the breaker too often, it will usually await to be pushed out of the way by the next oncoming train or tram. Inform the traffic control and emergency staff of the district in which the faulty vehicle is, and then leave the matter to them. Should the motorman ring in to your sub-station, tell him to keep his trolley clear of the line and wait to get pushed into a siding, and that the emergency men are on the way out.

Sometimes a fault of this nature will allow a vehicle to travel from one district to another between circuit breaker blowings. You can then tell where the vehicle is, and the direction of its progress by noting that it first blows the High Street circuit breaker, and then the Corn Exchange breaker opens two or three times. Word should be telephoned into the traffic office at once and they will meet the vehicle and take it off service.

Dead Shorts.

Dead shorts will declare themselves by bringing out the breaker very heavily, and not permitting its closure ; there is no mistaking them. Try three times with 20 seconds interval between each trial, and then inform the control or traffic office that you cannot keep that circuit breaker closed. Whilst trying on such faults, always put your jacket on, and turn up the coat collar. This often saves nasty burns due to flying hot copper or carbon particles lodging on the arms or neck. There is then nothing to do but await the arrival of the mains men to clear the trouble and ask for the breaker to be put in again. It must not be tried without their authority.

Vehicle Cable Faults.

Cable faults may come on as sudden dead shorts, or may give hours warning beforehand. In the latter case, the circuit breaker attached to a certain feeder will open not too violently, and will then go back again and stay in. Enquiry at the control or traffic office will give you the

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news after a while that they can find no cause for such happening; that no faulty vehicle, fault outside, or on consumer's premises has been reported. Report this fact to mains stand-by and if they have the time to spare get them to run over the feeder and its attached cables where possible with the megger. Even if the tests show everything all in order, the time has been well spent in settling the matter.

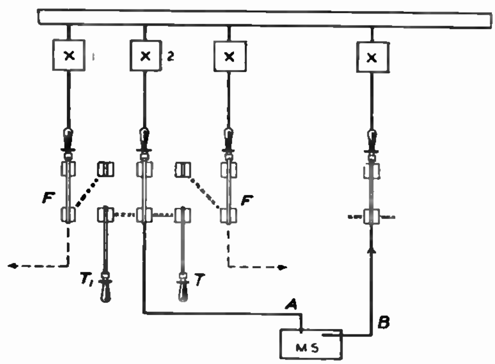
Often, however, it is not possible to test so promptly and possibly in two hours from the first blowing of that circuit breaker it will open again. This time a little more violently. If a cable fault is developing, the next blowing will follow in half an hour, and you can then be sure that either water has got in somewhere, or dirt has crept across an old sore in the cable somewhere up a duct, and put the cable to earth temporarily. The water or dirt is blown clear and dried out by the force of the flash over, and for a little while the place stands up; but each time the damage is increased, and each time the flash over takes place quicker until it becomes dead earth and leads to a stoppage. For that reason, get the mains stand-by on to the job as soon as this repeated blowing makes its appearance. They may then be in time to save serious delay and trouble.

Fault in Bitumen Type of Insulated Cable and its Detection.

Another type of cable fault is more rare to-day, as the bitumen type of cable insulation and laying is now obsolete. There is, however, still some of it left. As the heat of a partial earth will warm up the bitumen and seal over the bad place for a time, this type of cable is likely to be very treacherous. As a rule it will hold up until quite a heavy current starts to get to earth, and then the bitumen is gasified wholesale, which on reaching the air is likely to take fire and lead to an explosion. The station man can only rarely detect this type of fault; but if he notes that a certain feeder which at say 9 p.m. usually carries 500 amps. is carrying a steady 800 to 1,200, he should suspect trouble at once and get hold of the mains stand-by. The actual steadiness of the amperage and its heavy excess above normal are ample warning that trouble of the above type is starting.

Service Line Partially Earthed.

This fact of dead steady excessive load also indicates that other rare fault, possible with any type of cable, in which a service line or tapping into the system has gone partially to earth on to a steel casing, a street lamp standard or a tramway pole which has become improperly earthed. A cable rubs through, gets into contact



Arrangement of Inter-connector Switches at Sub-station so that it may be Closed Down and the Various Routes may be Fed from a Master Sub-station (MS).

A and B, cables to sub-station from MS; FF, feeder switches; inter-connecting switches, T_1 and T: circuit breakers, X.

with the metal, which whilst not earthed properly allows say 300 amps. to leak to earth. Insufficient to blow the circuit breaker on a circuit which takes 1,000 amps. at peak time and 500 normally, but sufficient to melt and burn the metal of the standard. Here again, the fault is not easy to detect, but regular attention to the feeder ammeters and a knowledge of what they ought to carry at a given time, renders a man suspicious when he sees 800 amps. *steady* at 10 p.m. where there ought to be 400 amps. fluctuating. Always ask the mains stand-by man to find out the reason for the extra loading. If it is all right then your enquiry does not matter; if it is all wrong, your keenness may have saved a costly bit of trouble. In any case, you get known as a man who lets nothing pass his observation.

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Circuit Breaker Settings.

Circuit breaker settings should never be interfered with by a sub-station man. If, during a block on a traction system the load drops off, and then mounts up furiously, and this must always be watched for, it is better to hold the circuit breaker in on that route than interfere with its setting.

If the cable is overloaded regularly at every peak time, report the matter and ask for an increased breaker setting, or for load to be taken off that cable; do not on any account make a permanent alteration in the setting yourself. Leave these points to the decision of the super.

Interconnector Switches.

Most modern switchboards for traction or similar purposes are arranged so that when that particular sub-station is shut down, the various routes may be fed from a master sub-station. This is arranged by having inter-connector switches as shown on the diagram.

MS is the master sub-station and feeds into the local sub-station through cables A and B, or, in turn, it may be fed by them in an emergency. F F are feeder switches feeding out from the local sub-stations and supplied mostly by the converters at that sub-station; during light running the local sub is shut down, and the feeders radiating from it are fed in groups from the master sub-station. Thus, cable A feeds into cables F and F through the inter-connecting switches T_1 and T.

Before shutting down the local sub, these inter-connectors are closed, and the circuit breakers XX, etc., opened. This deadens the bus bar at the local sub-station. Should a fault occur on one of the local cables, it is dealt with by the circuit breaker at the master sub-station. If the local circuits were just left in with their breakers closed and a feed sent down from the master sub-station, then any fault would trip the breaker locally, and if it were not automatic would keep the circuit open until a complaint was made. By throwing back the control to the master sub-station, attention is at once called to something wrong by the breaker at the master sub-station opening. The feeder B also supplies a group of local cables on either side of it through similar inter-connectors.

Another good feature of these inter-connector switches is that suppose during normal running with the local converters in service, the line fed by X1 became overloaded by trouble of a temporary nature; say clearing a block after a traffic stoppage, and that the breaker threatened to come out, or refused to stay in, then, by closing T1, current will also be fed to the overloaded cable through breaker X2, and the inter-connector switch. This can always be done provided that circuit X2 is not also heavily overloaded; it can be stated, however, that such a position does not occur. By the nature of things, a block on one part of the line must be cleared and got away, before the heavy traffic can reach another portion fed by another feeder.

On switchboards where such inter-connectors are not provided, keep a length of insulated cable on the lower portion of the switchboard platform, and have it fitted with good-sized lug terminals at both ends, on to which are screwed copper forks which can be pushed over a switch blade. Such a cable can then be used to connect heavy and light-loaded breakers to get through an emergency, or to allow a route to be fed through other than its own circuit breaker, whilst its own breaker is being cleaned and overhauled.

Cleaning Circuit Breaker After Heavy Blowing.

Always after heavy blowing, blow out a circuit breaker with hand bellows, clean it up well, and make a full report of any rough or blobbed contacts which are visible. Even if these will work fairly easily, see that they are overhauled the day following; otherwise the next blowing will find you with a breaker blobbed up, which will not close, and a circuit off for some few minutes while you make the breaker workable.

Keep note of all alarm signals, bells, or telephones which connect your sub-station with the master-sub, or with other depots, and on the slightest falling off in efficiency, such as a telephone bell ringing weakly, have the matter attended to at once.

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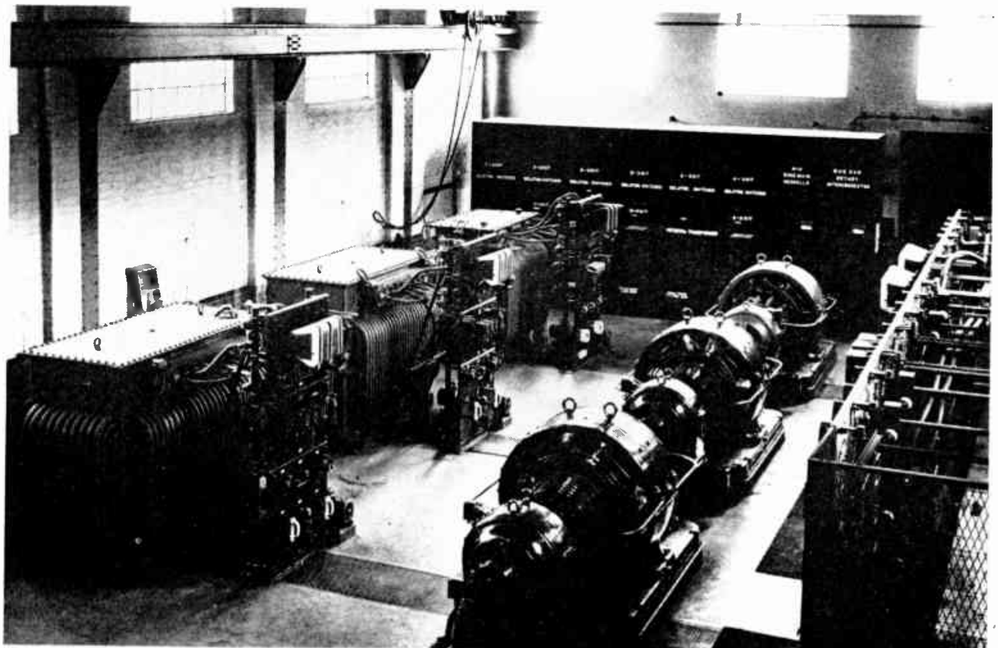
Master Sub-station Charge Hints.

When in charge of a master sub-station which controls semi-automatic subs at some distance, it is more than ever necessary to keep your records in good order. Above all, try to forget that the distant subs may take a load off your master sub-station and lower its output; bring the distant sub in immediately the pressure drops below a satisfactory working point at the distant sub-station, as shown by the pilot voltmeter. Both on lighting and power service as well as on traction, pressure must be maintained whether the machines at the distant subs are lightly loaded or not. That must be the first consideration; especially is this the case when the distant sub-station supplies a quarry, or a heavy rail or tram route on a steep gradient. Good pressure must come before machine efficiency; and your best recommendation is a well maintained voltage chart from the distant point.

It should also be unnecessary to warn a man against running distant subs under his control, in order to keep his place lightly loaded or to keep the temperature down in hot weather. This sort of thing, however, does happen, and it always stamps a man as undesirable.

Control of a master sub, having charge of distant semi-automatic sub-stations, is the natural step from manual sub-station work. It is interesting, responsible, and gives scope for a man to get to know the loading of a system thoroughly. There will be in the future, a good deal of such work to be done, as in many cases large undertakings like to have some amount of supervisory control over the key positions on a system. The outer positions can be left safely to purely automatic working; but with key positions it is a great convenience to be able to control them from a centre, and thus to alter and adjust the control they exert on sub-stations of a purely automatic nature around them.

From efficient control of a master sub-station a man passes naturally to control of a group.



THREE 500-KW. FULLY AUTOMATIC AND REMOTE CONTROLLED ROTARY CONVERTER EQUIPMENTS BY THE BRITISH THOMSON-HOUSTON CO., LTD., WITH D.C. CONTROL AND FEEDER BOARD ON THE RIGHT AND THE ROTARY CONVERTER STARTING PANELS MOUNTED IN FRONT OF EACH MACHINE TRANSFORMER. THE E.H.T. CONTROL BOARD IS IN THE BACKGROUND.

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THE CONSTRUCTION OF SMALL POWER TRANSFORMERS

By FRANK PRESTON, F.R.A.

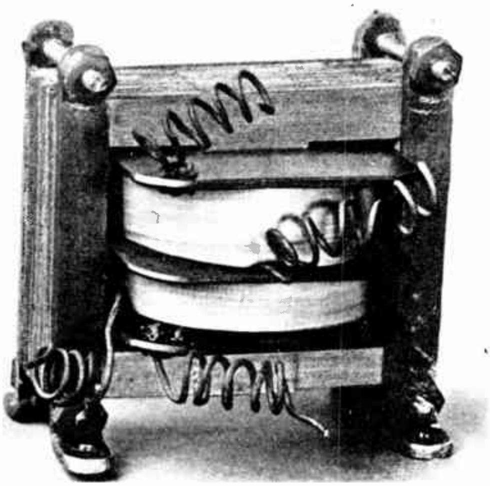

Fig. 1.—A SMALL TRANSFORMER MADE EXACTLY AS DESCRIBED IN THIS ARTICLE.
Details for making the core clamps and spools are given in the text. Direct connections can be made by means of the flexible leads.

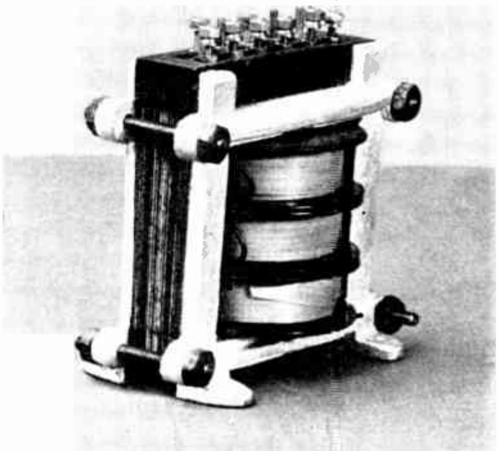

Fig. 1A.—ANOTHER SMALL TRANSFORMER WHICH MAY BE CONSTRUCTED.
In this case, use has been made of ready-made spools, core clamps and terminal block. This particular component has three secondary windings.

THE making of power or mains transformers is a piece of work that is often shirked by the electrician on the assumption that a good deal of tedious calculation and experiment is necessary before a satisfactory instrument can be produced. With a view to removing this latter difficulty, it is proposed to offer in concise and tabular form all the information which the practical man is likely to need in working out the design for any small transformer, be it required to give an output of only 6 volts, such as might be wanted for operating a bell, of 1,000 volts, for use with X-ray or similar apparatus, or of any intermediate figure.

It should be pointed out in the first place that mere calculation is insufficient for determining the details of construction and that experience is often of far more use. The information I shall give is that obtained by combining theory and practice, and by making full use of the experience gained from "trial and error" methods.

PRELIMINARY CALCULATIONS.

Calculating Output in Watts.

In working out our design, the first point to consider is that of the power, in watts, with which our transformer has to deal. This can be done by adding together the wattage of the secondary, or output, winding and a reasonable percentage loss which must inevitably occur in the iron core and in the windings. In practice it is sufficiently correct to base the figure for losses at some 25 per cent. of the output power; this assumes an efficiency of 80 per cent., which we can safely expect to obtain.

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As an example, let us suppose that we require an output of 160 volts at .25 ampere. The secondary wattage will therefore be 160 × .25, or 40 watts; adding 25 per cent. to this we get the total figure of 50 watts.

Finding Size of Core Stampings Required.

We can now find the size of core stampings required by consulting Table I. Thus we see that No. 4 stampings will suit our purpose, provided that they will accommodate the necessary number of turns—this latter point will be settled later.

Perhaps we had better take another example just as a check on the method, this time assuming that an output of 500 volts at .2 ampere is called for. The output watts will be 500 × .2, or 100 watts; adding 25 per cent. we can see that the core must be capable of handling 125 watts and that No. 33 stampings will therefore be suitable.

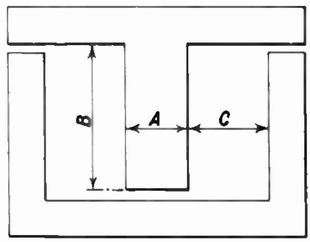

Fig. 2.—Dimensions of Core Stampings Detailed in Table I.

Gauge of Wire and Number of Turns.

Having decided on the core size, the gauge of wire and number of turns required must be found. Reverting to the first example, where the secondary current is .25 ampere, and then referring to Table No. 2 we see that the gauge of wire most suitable for carrying such a current without undue heating is 30's. The total number of secondary turns required can now be found by multiplying the voltage (160 in this case) by the "turns per volt" given in Table I. Hence we get the result of 160 × 8, which equals 1,280. Next we must consider the primary winding. This has to deal with the same power as we found for the core, i.e., 50 watts; the primary current can thus be found by dividing the mains voltage into 50. Supposing the voltage to be 250, we see that the primary current will be 50/250 or .2 ampere. Referring to Table 2 once more it is seen that 30's gauge wire is again most suitable.

The number of primary turns is found in exactly the same way as those for the secondary, by multiplying the "turns per volt" of the core stampings employed, by the voltage; otherwise 8 × 250, or 2,000.

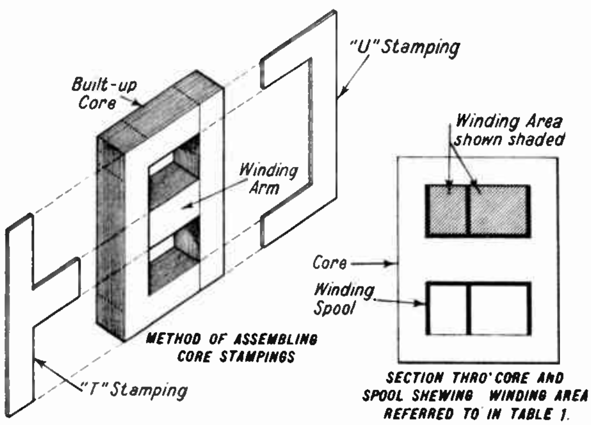

Fig. 2A.—Details for Making Core.
Showing the method of assembling core stampings. Also, the winding area as referred to in Table 1.

Winding Area.

Before commencing the constructional work, we must make quite sure that the calculated number of turns will fit on the core provisionally decided upon. This can be done by using our tables again. For instance, from Table II it is found that 5,370 turns of 30's gauge enamelled wire can be accommodated in 1 sq. in. of "winding area" (see Fig. 2A), and thus our secondary winding of 1,280 turns will require a space of 1,280/5,370, or about $\frac{1}{4}$ sq in.

Similarly for the primary. Our 2,000 turns of 30's gauge enamelled wire will occupy rather more then $\frac{1}{3}$ sq. in. The total winding area required is thus just over $\frac{1}{2}$ sq. in., and the area provided by No. 4 stampings is seen from Table I to be $1\frac{1}{2}$ sq. in., and therefore that

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Table 1.—CORE DETAILS FOR "T" AND "U" STALLOY STAMPINGS.

Size Number of Stampings.	Dimensions.			Quantity of Stampings. (Pairs).	Approx. Max. Watts.	Turns per Volt (for 50 Cycles).	Approx. Winding Area.
	A.	B.	C.				
	ins.	ins.	ins.	doz.			sq. in.
4	$\frac{15}{16}$	$2\frac{5}{16}$	$\frac{7}{8}$	6	50	8	$1\frac{1}{2}$
4A	$\frac{15}{16}$	$1\frac{1}{2}$	$\frac{7}{8}$	6	45	8	1
5	$\frac{5}{8}$	$1\frac{1}{2}$	$\frac{3}{4}$	6	30	12	$\frac{3}{4}$
28	$1\frac{1}{4}$	3	$1\frac{1}{4}$	6	250	6	3
29	2	$4\frac{1}{2}$	$1\frac{3}{8}$	6	300	4	$5\frac{1}{4}$
30	$\frac{15}{16}$	$1\frac{1}{8}$	$\frac{7}{8}$	6	45	8	$\frac{3}{8}$
30A	$\frac{15}{16}$	$\frac{13}{16}$	$\frac{7}{8}$	6	40	8	$\frac{3}{8}$
30B	$\frac{15}{16}$	$\frac{1}{3}\frac{1}{2}$	$\frac{7}{8}$	6	35	8	$\frac{1}{4}$
31	1	$3\frac{1}{2}$	1	6	100	8	$2\frac{7}{8}$
32	1	$2\frac{1}{4}$	1	6	75	8	$1\frac{3}{4}$
33	$1\frac{1}{4}$	$2\frac{3}{4}$	1	6	125	6	$2\frac{1}{4}$
35	$1\frac{1}{2}$	$3\frac{3}{4}$	$1\frac{5}{8}$	6	200	5	$5\frac{1}{4}$

Table 2.—WIRE DATA.

Standard Wire Gauge.	Working Current in Amps.	Enamelled.		Double Cotton Covered.	
		Winding Turns per sq. in.	Yards per pound.	Winding Turns per sq. in.	Yards per pound.
16	6.5	220	26.3	173	25.5
18	3.6	392	46.9	297	45.4
20	2.0	685	83.3	472	79.4
22	1.25	1,110	137	692	129
24	.76	1,770	221	977	203
26	.51	2,560	330	1,280	294
28	.35	3,760	488	1,630	422
30	.25	5,370	694	1,990	587
32	.18	6,890	915	2,550	755
34	.133	9,610	1,202	3,020	1,024
36	.1	13,500	1,840	4,110	1,477
38	.06	20,400	2,810	5,100	2,287

size of stamping will be amply large.

At this juncture it should be mentioned that the "turns per square inch" in Table II are worked out on the assumption of perfectly even winding (which is impossible in practice), and also that the "winding area" of Table I makes allowance only for the space occupied by the spool, and not for any insulation between layers such as might be advisable in practice. In consequence of this it is necessary to add 20 per cent. or so to the calculated area required for the windings.

Frequency of Supply.

There is yet another point to consider. The "turns per volt" of Table I apply only when the supply is at a frequency of 50 cycles, but actually the figures will be sufficiently accurate for any frequency between 40 and 100 cycles. For a frequency of 25 cycles, however, *twice as many* turns per volt must be allowed if anything like reasonable efficiency is to be obtained. For example, 16 turns per volt must be used on No. 4 stampings when the transformer is to work from 25-cycle mains.

CONSTRUCTIONAL DETAILS.

We can now consider the purely practical aspects of transformer construction, bearing in mind that the methods will be just the same whether the instrument is to handle 10, 50, or even 300 watts.

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The Winding Spool.

The first job is to make a winding spool to fit the stampings decided upon. One very good form of construction is shown in Fig. 3, but there are many others which will suggest themselves to readers.

The spool illustrated is made up from a sheet of $\frac{1}{16}$-in. thick fibre and a strip of wood $1\frac{1}{16}$-in. wide by $\frac{3}{16}$-in. thick. First of all two pieces of wood equal in length to the winding arm (B) of the core are cut off and a $\frac{1}{16}$-in. rebate is made at

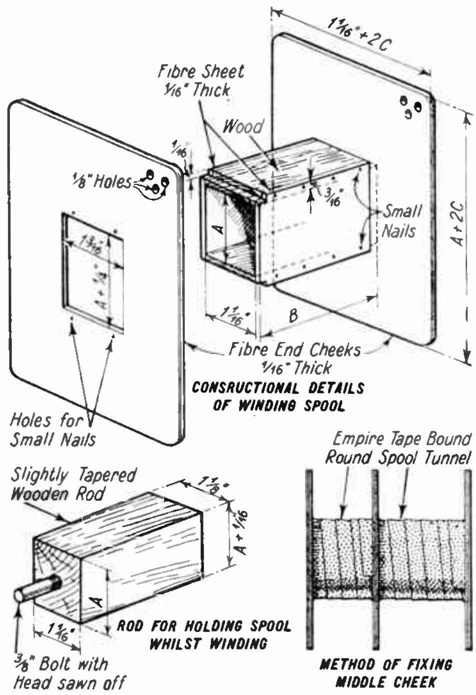

Fig. 3.—PARTICULARS OF THE WINDING SPOOL.

each end by sawing. Next, two pieces of fibre equal in length to the wood and having a width of A (the width of the winding arm) plus $\frac{3}{8}$-in. are cut out, by means of either a tenon saw or a sharp chisel. These have a $\frac{1}{16}$-in. notch cut out of each corner and are then nailed to the strips of wood so as to form a rectangular "tunnel." Before proceeding further, the edges of the tunnel should be smoothly rounded off with fine glass paper to remove any sharp angle which might tend to cut the wire. Lastly, the two end cheeks should be prepared according to the dimensions given (the letters "A" and "C" refer, of course, to the core dimensions shown in Fig. 2 and detailed in Table 1).

In order to ensure that the end cheeks will be a perfectly tight fit on the tunnel, it is best to make the holes rather too small at first and then to open out with a file. Besides the two end cheeks shown, a third one will be necessary for all spools longer than, say, 1 inch, to act as a division between primary and secondary windings; this should be made to fit tightly over the tunnel.

The next step is to give the whole spool a very liberal coating of thin shellac varnish and to dry it quickly by placing it in a warm (not hot) oven, or by holding it near to a fire.

Even though the middle cheek has been made to fit tightly on the tunnel, it will be wise to adopt some means of preventing it from being forced out of position by the pressure of the windings. This can most easily be done by winding a few turns of Empire or insulating tape in the two sections of the spool as shown in a detail of Fig. 3. Before applying the tape the cheek should be so arranged that the lengths of the two sections are proportional to the areas required for primary and secondary windings.

Winding.

The spool is now ready to receive the windings and should be mounted in such a way that it can easily be rotated. First of all a tapered wooden rod should be made to fit tightly into the tunnel and the whole can then be set up in a lathe, when such a machine is available. Failing the lathe, a hand drill held horizontally in a vice will prove a good substitute if the wooden rod is fitted with a $\frac{3}{8}$-in. bolt (with the head sawn off) as shown in Fig. 3. When neither of the tools mentioned is accessible the winding can be done entirely by hand by making the wooden rod 3 or 4 inches longer than the spool so that it can easily be gripped.

Whatever method of winding is finally decided upon the bobbin of wire to be used should be fitted in some kind of a holder so that the wire can easily be drawn

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off without causing it to become entangled; a suitable holder is shown in Fig. 8.

Counting the Turns.

When the winding apparatus has been arranged a length of flex should be soldered to one end of the wire, using a perfectly non-corrosive flux, such as resin, the joint being covered with Empire tape secured with Chatterton's Compound. The flex should now be secured to the end cheek by threading it through the three ⅛-in. holes, and winding commenced. There is some little difficulty in counting the turns but it can be overcome when using a lathe for winding by finding the exact number of revolutions per minute (from 60 to 80 will be found most convenient) and multiplying this figure by the "time of running." Of course, it will be still easier if a revolution counter can be obtained, or devised from a cycle distance meter. In the case of a hand-drill "winder," the counting will not prove too difficult if the gear ratio between the handle and chuck is first worked out. When winding by hand the only really satisfactory way is to count every turn, and although this is rather tedious it does not present an insurmountable difficulty.

Binding in Insulating Tape.

The turns should be wound as evenly as possible, preferably by working from end to end and arranging them in layers. A fair tension should be kept on the wire but this should not be sufficient to cause stretching or to force any turn past the layer which is being wound. To prevent the possibility of short circuits between turns at widely differing potentials a layer of Empire tape should be bound round the winding after every "50 volts" or so, and no later turns must be allowed to slip past it. After putting on the requisite number of turns for one winding another length of flex should be soldered on, taken once or twice round the spool and anchored in the holes of an end cheek. The complete winding can then be covered with two or three layers of Empire tape, using Chatterton's Compound as adhesive.

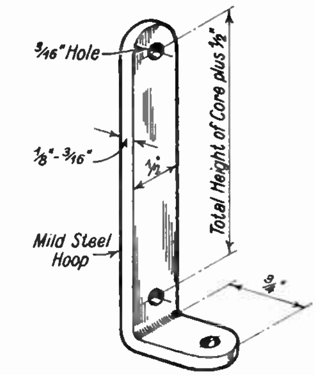

Fig. 3A.—SUITABLE DIMENSIONS FOR CONSTRUCTING CORE CLAMPS, FOUR OF WHICH WOULD BE REQUIRED FOR ONE TRANSFORMER.

When the spool is divided into two parts, the second winding can be put on in exactly the same manner as the first, but with a shorter spool it is more convenient to place the secondary on top of the primary, taking great care that there is ample insulation (three or four layers of Empire tape) between them.

Assembling the Core.

The core stampings can next be fitted into the spool, arranging them in the manner illustrated in Fig. 2A; "T" and "U" stampings are inserted alternately from both ends so that they interleave. It will be noticed that one side of each stamping is white, due to its being covered with a film of insulation, and the object of this is to insulate each stamping from its neighbours; the white sides of every stamping must thus face in the same direction. The winding spool specified will take rather less than the full six dozen pairs of stampings, but if the latter are packed fairly tightly (without

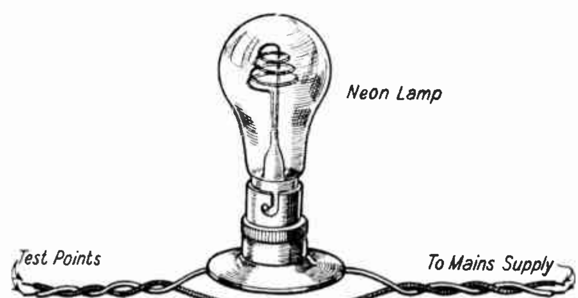

Fig. 4.—THE SIMPLE APPARATUS REQUIRED FOR TESTING TRANSFORMERS FOR GOOD INSULATION AND CONTINUITY OF WINDINGS.

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using undue force) there will only be a few left over.

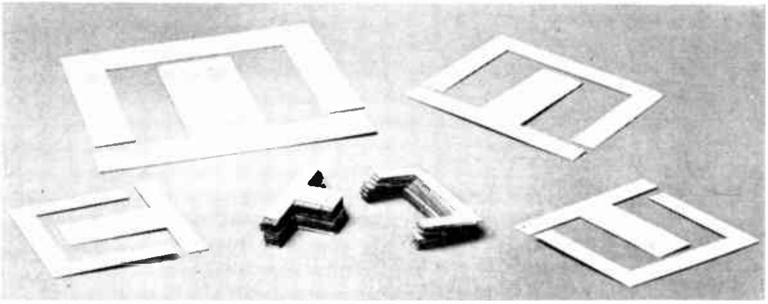

Fig. 5.—A SELECTION OF "T" AND "U" STALLOY STAMPINGS OF VARIOUS SIZES.

Core Clamps.

It now remains to fit clamps which will make the whole structure quite rigid. These can be made as in Fig. 3A, or may be obtained ready-made in the form of castings as shown in Fig. 6.

Lastly, some means of connecting up the transformer must be devised. If desired the flexible leads from the windings can be connected directly to the appropriate points, but a rather neater job will result if an ebonite terminal strip is fitted in the manner shown in Fig. 1A; in that case, the flexible leads should be well soldered to the terminals.

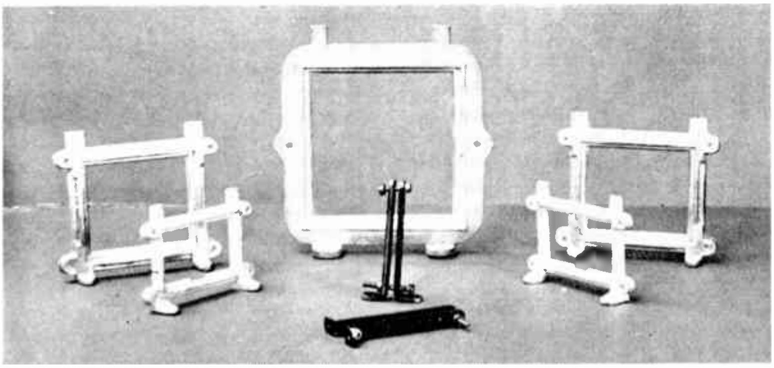

Fig. 6.—A SELECTION OF CORE CLAMPS.
In the centre is a set similar to that detailed in Fig. 3A. The others are castings which can be obtained ready-made.

Multiple Outputs.

When two or more different voltage outputs are required from the same transformer, such as for battery charging through a valve rectifier, or for wireless purposes, the method of procedure will be only slightly different from that described above. In computing the power to be handled by the core and by the primary winding the wattages of all the secondaries must be added together. Each winding may be put in a separate section of the spool, by fitting additional dividing cheeks, or the secondaries may be placed one on top of the other, provided that ample insulation is allowed between each. The former method is generally to be preferred since the windings are then more accessible, but the latter has the advantage of compactness.

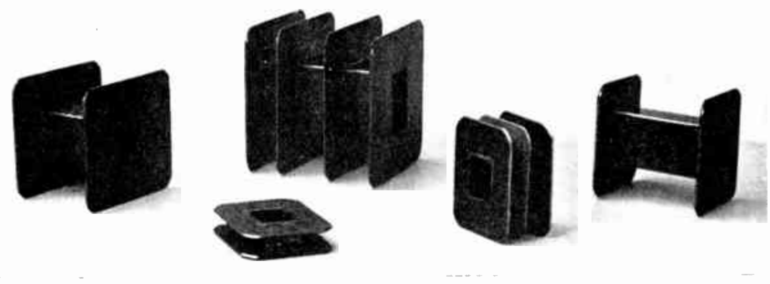

Fig. 7.—VARIOUS WINDING SPOOLS OF THE TYPE SUGGESTED IN THIS ARTICLE.

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Testing the Transformer.

Before putting the transformer into commission, it is advisable to apply a few simple tests for continuity of windings, insulation and so forth. In addition to these, if a very accurate secondary voltage is required it should be measured whilst on full load and any necessary slight adjustments made to the number of secondary turns.

The simplest way of applying continuity and insulation tests is by means of a neon lamp connected as shown in Fig. 4. The test points should be applied between (*a*) the ends of the primary winding; (*b*) the ends of the secondary winding; (*c*) primary and core; (*d*) secondary and core; and (*e*) primary and secondary. In tests (*a*) and (*b*) the lamp should glow continuously, but in (*c*), (*d*) and (*e*) there should be no more than a faint instantaneous glow on first making connection. It is essential that the wires should not be touched with the fingers whilst testing because sufficient current would then pass through the body to operate the neon lamp.

Notes in Connection with the Tables.

A few final notes are called for in connection with the compilation of Table II, particularly in regard to the "working current in amps." This is not the maximum current carrying capacity of the wires, but is that current which can be carried without appreciable temperature rise and is based on a current density of approximately 2,000 amperes per square inch, which is a suitable figure for small transformers of the type discussed. Any of the wires listed could be used to carry a heavier current than that specified, but the transformer would then heat up appreciably whilst in use, especially if it were to be used for long continuous periods. Many designers even work on a current density of 1,500 amperes per square inch, but I do not find this by any means necessary, unless the transformer is to be mounted in such a position that there cannot be a free circulation of air round it. When a component is to be used under the latter conditions it might be well to play for safety by using the next larger gauge of wire to that found from Table II. The same rule may also be applied if for any reason the working temperature of the transformer must be kept down to a minimum. In actual fact the working temperature of transformers constructed according to the data given should not exceed about 45° Centigrade.

Particulars of both D.C.C. and enamelled wires are given, but it is generally most convenient to employ material of the latter kind for all gauges less (higher

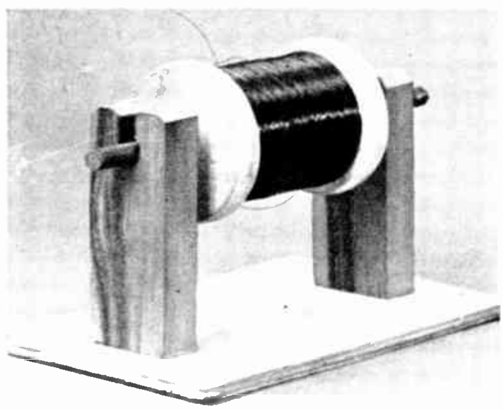

Fig. 8.—A Convenient Reel Holder Made From Three Pieces of Wood and a 4-in. Iron Rod.

number) than 24's. For thicker wire D.C.C. is better, since there is some tendency for enamel to crack and so cause short-circuits. When cotton covered wire is employed it is always best to give it a liberal coat of shellac varnish to prevent the ingress of moisture which will act as a fairly low resistance across the turns.

Where Materials can be Obtained.

Stalloy core stampings are obtainable from Messrs. Lumen Electric Co., Scarisbrick Avenue, Litherland, Lancs. This firm also supplies core clamps and built-up spools of the kind illustrated, as well as all other materials required for the construction of small power transformers, such as wire, shellac varnish and Empire tape.

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FIRE PROTECTION PLANT

APPLICATION TO GENERATING PLANT, SWITCHGEAR AND TRANSFORMERS

By H. E. HUTTER, A.Am.I.E.E.

Fig. 1.—EXTINGUISHING AN OIL FIRE WITH CARBON DIOXIDE GAS.
The stream of gas is directed on to the fire from a specially shaped horn. This is connected by hose to portable CO_2 cylinders, each containing 50 lb. of liquid CO_2, under high pressure. When the gas is turned on at the cylinders, the liquid flows through the hose and expands in the horn. Here it drops in temperature and is ejected as a finely divided cloud of actual solid and gaseous CO_2, forming an effective blanket on the fire. The operator can turn off the supply at the nozzle. See also Fig. 6.

THE provision of adequate fire protection plant for electrical machinery, apparatus and buildings is an insurance against the heavy financial losses incurred, both in loss of revenue and damage to plant, by shutdown due to fire.

The necessity of using large quantities of oil in switchgear and transformers greatly increases the risk of fire, while faults on rotating machinery are liable to cause extensive damage by small fires unless speedily extinguished.

The Two Fire-fighting Systems.

The specific risks mentioned above can be adequately covered by the use of either CO_2 gas or the foam system. Each system has its special applications, which are dealt with below.

THE CO_2 GAS SYSTEM.

For Interior Protection.

The use of CO_2 gas is limited to apparatus situated in chambers normally enclosed, except for windows and doors, or which can be subdivided if required. Given suitable conditions, CO_2 is a most efficient fire extinguisher. Saturation of the air with 15 per cent. of CO_2 gives a condition under which combustion cannot exist. A fire is extinguished by the descending heavy gas in a few seconds.

Characteristics of CO_2 Gas.

The gas is non-poisonous and non-corrosive; the dielectric strength being higher than that of air, permits discharge amongst high voltage gear with safety. The gas, being heavier than air, will remain

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upon the site without dispersing unless exposed to draughts.

The Equipment Required.

The gas is stored in steel cylinders, the largest containing 50 lb. of liquefied gas under 700 lb. per square inch pressure, the gaseous volume on discharge being 400 c. ft. An installation consists of one or more cylinders each fitted with a special valve and connected to a common manifold. The gas remains in liquid form until actually discharged from the nozzles to prevent any trouble from freezing in the pipes due to too rapid expansion.

The quantity of gas required should be sufficient to allow a saturation of 30 to 50 per cent.; this gives a considerable factor of safety over the 15 per cent. mentioned previously, and allows for loss through the gas drifting away.

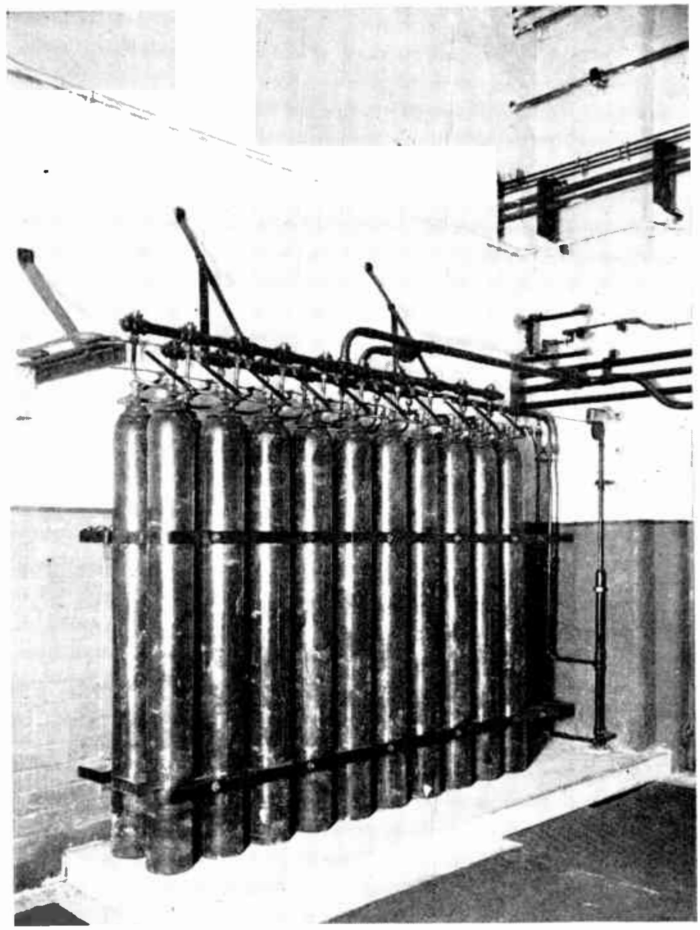

Fig. 2.—AUTOMATIC CO_2 FIRE PROTECTION IN A POWER STATION. Here we see a battery of liquid CO_2 cylinders protecting the equipment in six different rooms. Fig. 3 illustrates the valves and piping connected with the cylinders. (*Lux*.)

Hand or Automatic Operation.

The cylinders may be operated by hand from either local or remote stations or automatically. In the latter case asbestos roller blinds are dropped over all windows and openings to prevent loss of CO_2 and influx of fresh air.

Fire detectors are located at strategic positions in the protected area when automatic operation is desired.

PROTECTION OF ROTATING MACHINERY.

Full protection to generating plant operating with closed ventilating systems can be given without any structural alterations. If the system is non-circulating the addition of automatic dampers is required. Gas discharge nozzles are located in the ventilating ducts. On operation of the gas cylinders the dampers are closed. The creation of excessive static pressure due to gas discharge is obviated by the provision of a by-pass duct.

Method of Automatic Operation.

A fire may be caused by an earth on one phase, in which case the automatic trips would operate. The electrical operating relay of the gas system is interconnected with the generator relays. In practice it is

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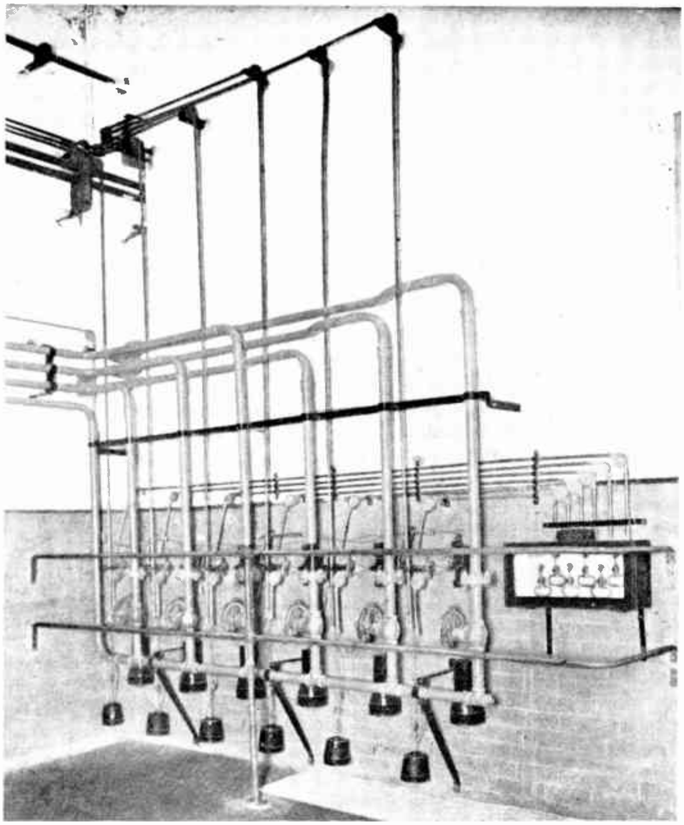

Fig. 3.—AUTOMATIC CO_2 FIRE PROTECTION IN A POWER STATION. The weight-operated valves for the battery of CO_2 cylinders illustrated in Fig. 2. On the outbreak of fire in any of the six rooms, the heat melts a fuse. This releases the tension on the wire and the weights connected to it automatically drop, thus operating the pipe and CO_2 battery valves. The CO_2 then rushes through piping to the nozzles in the room affected. Note the six branch pipes, each with a weight-operated valve. These pipes are taken off the main pipe from the battery.

found that no matter how quickly the trips operate, some damage is always done and the risk of fire consequently great. During the period of deceleration, if safety measures are not adopted, this fire may assume serious proportions. Following an initial discharge of gas further cylinders are released at intervals of four to eight minutes during the period of deceleration. By this means complete extinction is accomplished and the fear of reignition, whilst the machine is stopping, is eliminated.

It will be appreciated that there is no cleaning or drying out of the windings required after gas operation such as is necessary after the use of other mediums.

THE FOAM SYSTEM.
For Protection of Equipment Fully or Partly Outdoors.

The protection of transformers and oil switches which are mounted outdoors or situated in bays which are partly open is effected by the use of foam, which is practically the only medium that can be used which is not affected by the wind or draughts.

How the Foam System Operates.

The arrangement of the foam distribution system is such that any fire due to the fracturing of a transformer casing is taken care of whether it be on the ground or on top of the transformer, and also flames burning at the fracture due to an escape of volatile gases.

Foam is formed by the addition of water to a powder composed of an acid, alkali and a stabiliser. CO_2 gas is given off in the form of very tough bubbles, which expand and form the foam. The volume of the foam given off is 10 times the quantity of the water used.

The powder is inserted in the foam generator in cartridge form, rapidity of loading being an important essential with the system. The foam is projected from the generator by the chemical action set up and then led through rubber-lined hoses or fixed piping to the nozzles from which it is discharged.

The capacity of the foam generator is based on the largest area to be protected; a minimum of 6 ins. of foam is allowed

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over the area. When a number of different areas are to be protected the largest is selected for calculating the generator capacity.

A liberal discharge of foam can be given over the switch or transformer, the quantity being such that it will flow quickly down and spread over the floor. In situations where the floor area is comparatively large special discharge points are located at ground level.

The main discharge is limited to the ground area in situations where there may be dangers of coming in contact with high voltage conductors.

Putting Out Burning Oil Fire.

It is found that with most fires on electrical equipment the circumstances are such that the oil container discharges the oil to the ground, either by fracture or overflowing, and that this burning oil not only flows over a considerable area, but has the effect of maintaining the heat application to the oil container.

A quick discharge of foam to the floor area thus speedily reduces the area of the fire and enables the portable extinguishers to be brought into use to deal with the fire amongst the high voltage gear above the transformer.

An important advantage of foam is that where burning oil has been covered with foam, not only has the fire been extinguished, but there is also no danger of reignition for a number of hours, the

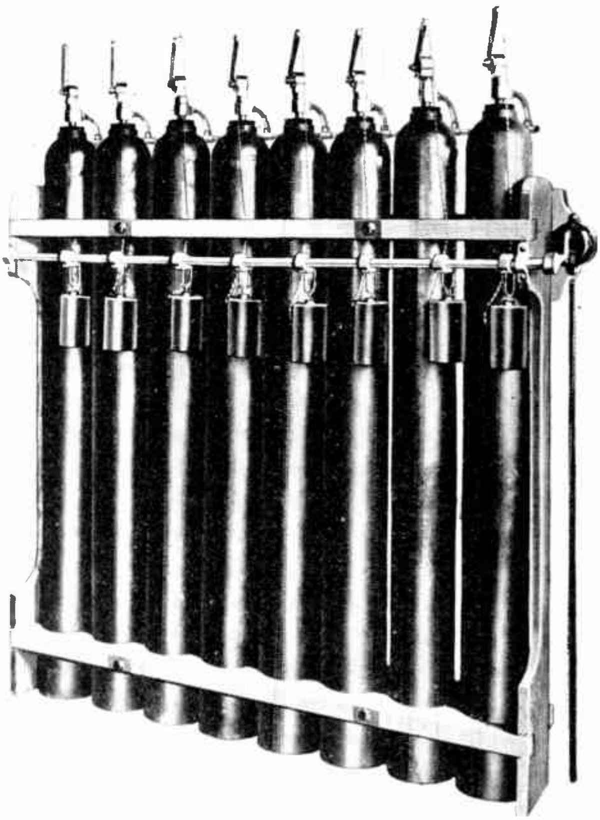

Fig. 4.—BATTERY OF CARBON DIOXIDE GAS CYLINDERS.

The valves for releasing the CO are operated by drop weights. Note the cams for releasing the weights.

Fig. 5.—A FOAM GENERATOR OF LARGE CAPACITY (" PHOMENE ").

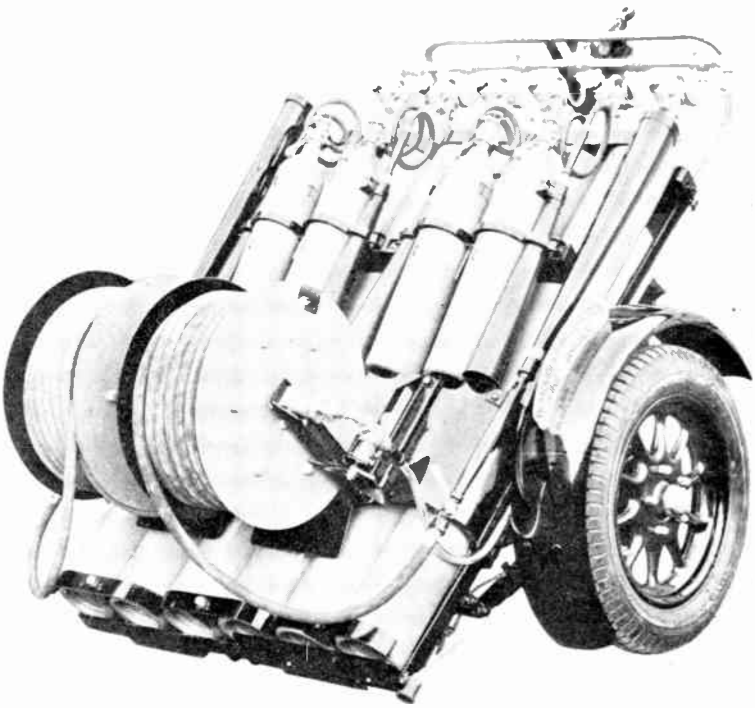

Fig. 6.—A Fire Engine Trailer for Fighting Electrical Fires.

The equipment consists of six large cylinders each containing 50 lb. of liquid CO_2. These are coupled to two hose reels and nozzles. In addition there are four portable cylinders, each with a nozzle. Similar equipment is shown in operation in Fig. 1. (*Lux.*)

and mounted on wheels for use indoors or out. No separate water supply is required. The larger sizes are capable of throwing a 50-ft. jet which remains steady in operation. A large number of these equipments have been provided for the protection of the C.E.B. Grid substations in England.

CO_2 Portable Unit.

The CO_2 portable unit consists of a small cylinder of gas mounted on wheels and provided with hose and a special foam forming an effective blanket.

A fixed foam installation may also have an associated foam hydrant, or foam discharge through nozzles. Foam being a poor conductor of electricity, care must be exercised where the jet is played.

PORTABLE EXTINGUISHING APPARATUS.

Four types of portable apparatus are in use for power station use: Foam, CO_2 gas, tetrachloride and the soda acid type.

Foam Type.

The foam apparatus is made in a number of different capacities from 2 to 30 galls. The apparatus is entirely self-contained

Fig. 7.—Portable Foam Extinguisher.

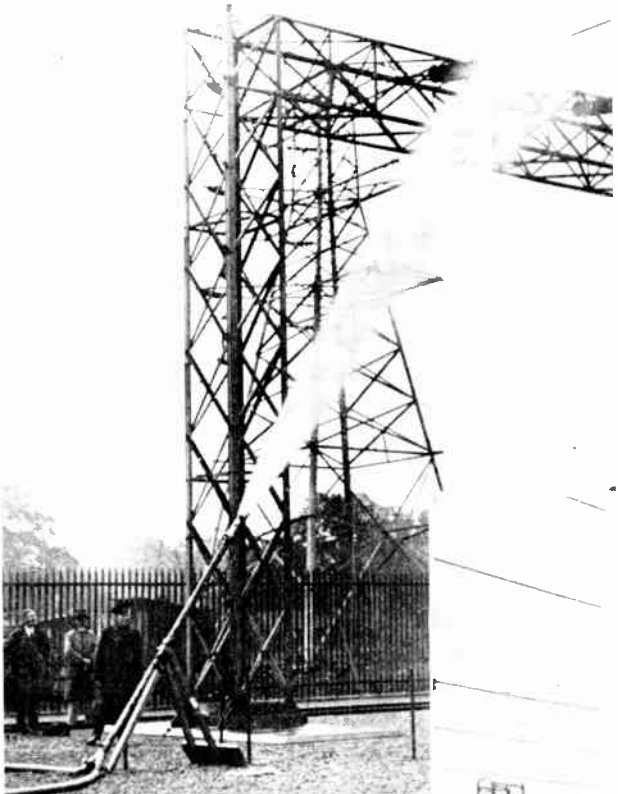

Fig. 8.—Croydon Substation Trials on High Voltage Line.
Testing resistance of the jet of water using a type of nozzle which produced a spray. As would be expected, the resistance of the jet was very high. With a jet of 27 ft. and using a nozzle of $\frac{5}{8}$ in. diameter, the resistance is many megohms.

nozzle. A smaller unit is available for carrying on a man's back. No ill effects are felt by the operators of these units from the gas.

Tetrachloride.

The tetrachloride type is best suited for use amongst high voltage gear. The liquid being of a very high insulating character, no risk of shock is possible. The liquid is directed on the flames and on coming in contact with them is vaporised, a heavy gas being given off. The gas falls, acting as a blanket on the flames and preventing free access of the air essential for the support of combustion.

Soda Acid.

The soda acid type is unsuited for electrical use, but meets with some scope in boiler houses and similar locations.

THE CROYDON SUBSTATION TRIALS.

Is there Danger to Firemen from Overhead Line?

Fears have sometimes been expressed that firemen will be

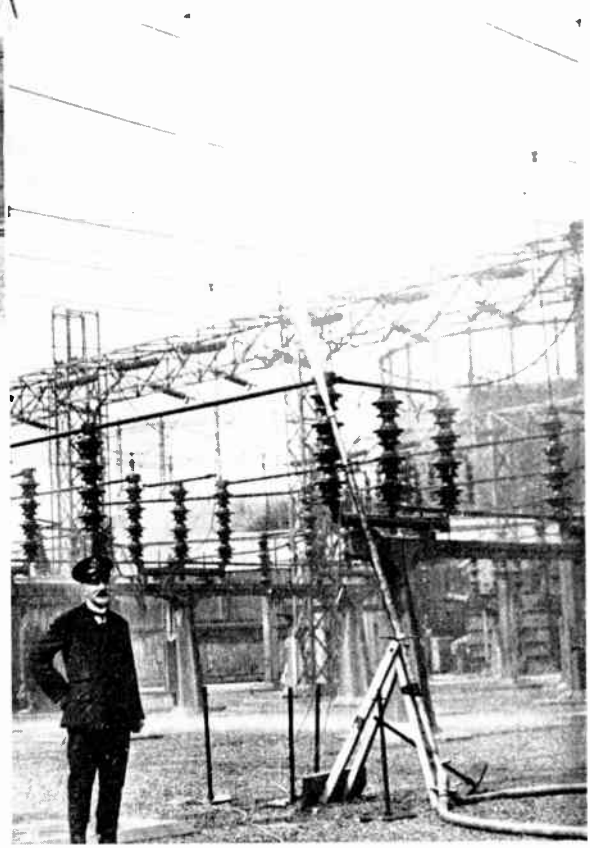

Fig. 9.—The Croydon Trials.
Distance between nozzle ($1\frac{3}{8}$ in. dia.) and live conductor is only 22 ft. The resistance of the jet is .33 megohm.

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subjected to danger, if, when dealing with a fire, they accidentally allow jets of water from their hoses to impinge on an adjacent overhead line.

A previous test, carried out at Bedford on the 23rd November, 1932, had indicated that a 132 kV. line could be sprayed by hand without any danger, a ½-in. nozzle being used and the length of the jet of water being about 40 feet. Calculations showed that if the water jet had remained "solid" instead of breaking up into fine spray, then a small but easily measurable voltage should have appeared between the hose nozzle and earth. Accordingly, the Institution of Fire Engineers suggested that another test should be made using jets of shorter length and larger diameter in an endeavour to obtain a more or less "solid" stream of water from the nozzle to the live conductor.

This additional test was made at Croydon substation recently, the hose being arranged as shown in Figs. 8 and 9. A voltmeter, located in one of the substation buildings, was connected between the hose nozzle and earth.

Details of the test are given in a report issued by the Central Electricity Board.

Test Results.

The resistance between the nozzle and earth, the hoses being full of water, was found to be 1,500—1,600 ohms, while the resistance of the water used was 2,100 ohms/cm³.

It will be seen from the results plotted in Fig. 10 that the resistance of the jet is

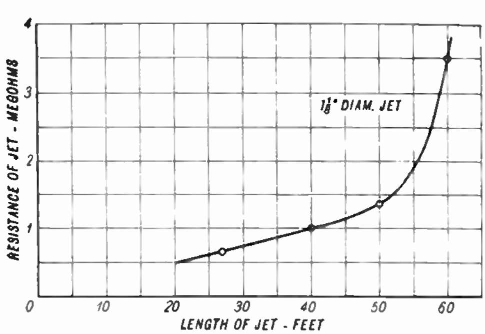

Fig. 10.—Resistance of Water Jets (1⅛ in. Dia.) of Various Lengths.

directly proportional to the length of the jet until the jet reaches a length of about 50 feet when it begins to break up into a spray and the resistance increases rapidly.

Fig. 11 shows how the conductivity of the jet varies with the cross-sectional area

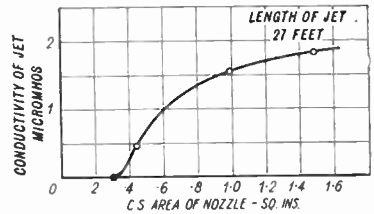

Fig. 11.—Showing How the Conductivity of the Water Jet Varies with the Cross-sectional Area of the Nozzle.

of the nozzle, the length of the jet being constant (27 feet). The conductivity in the case of the ⅝-in. diameter nozzle is very small, but the conductivity increases rapidly for a nozzle of about ¾-in. diameter as the stream of water becomes more "solid." For the larger sizes of nozzle (over 1 in. diam.) the conductivity does not increase so rapidly with the area of the nozzle as a larger proportion of water fails to make contact with the conductor.

Conclusions.

It is considered that no special precautions need be taken when working at 40 feet or more from a 132 kV. line and using nozzles having a diameter of ⅝-in. or less. When using nozzles having a diameter of ¾-in. or greater, the distance to the line should be at least 60 feet.

If it is necessary to work at shorter distances from the lines than those mentioned above, then, although there will usually be no serious danger, it is advisable as a precautionary measure to connect the nozzle of the hose to earth, or to use a hose having a copper wire running throughout its length and bonded to the nozzle and the hydrant, or to use a nozzle covered with an insulating material such as bakelite, or alternatively, to hold the ordinary type of nozzle with rubber gloves.

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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.

A Transformer Problem.

SIR,—The auxiliary plant in the works is supplied from two 300-kW. 400-volt 50-cycle transformers in parallel. Due to a breakdown in the H.T. switch feeding of one of the transformers, we had to transfer that transformer to our standby power station, the H.T. feeder of which is supplied from the same H.T. busbars in the supply company's substation as supply the other station. In energising the transformers, we found it impossible to parallel them, as there was a difference of 200 volts between two phases, and 560 volts between the remaining phase and either of the others. Reversal of the connections on the L.T. side of the transferred transformer failed to alter the conditions and the alteration had to be made on the H.T. side to remedy the fault.

Why was it impossible to rectify the fault on the L.T. side? The transformers are connected: Delta H.T., star L.T. Would this condition arise if the connections were: Star H.T., star L.T.?

J. B. (Glasgow).

(*Readers are invited to reply. All letters published will be paid for at the usual rate.*—ED.)

Colouring of Phases.

SIR,—Mr. D. Winton Thorpe in his article on the I.E.E. Wiring Rules states that the British Standard Specification No. 158 definitely fixes the colours for three-phase work as red, white and blue for phases and black for neutral.

Now the local Corporation Electricity Department use the colours red, blue and *green* to mark their three-phase supply, and I was under the impression that this was the correct method.

Your comments on this matter would be much appreciated.

W. T. (Blackpool).

British Standard Specification No. 158 fixes the correct colouring of a three-phase system with earthed neutral as follows:—

For the phases, red, white (or yellow) and blue. For the earthed neutral, black. In the case of three-phase three-wire, the colours red, white and blue are used alone. In the case of three-phase four-wire, with insulated neutral, the colour green is substituted for the colour black for the neutral.

Our correspondent refers to the Blackpool Corporation Electricity Department as using the colours red, blue and green to mark their three-phase supply. It may be that theirs is a two-phase supply with insulated neutral; this would result in the colours red and blue being used for the two phase-wires and green for the insulated neutral.

In general, the colours red, white and blue are the standard for phase colouring, with the qualification that the colour yellow may be used as an alternative to white if it is desired. The neutral should be either black or green or a combination of both—black if it is earthed, green if it is insulated, and striped if it is earthed through a limiting resistance. The colours are represented graphically by the initial letter R for red, Y for white or yellow, B for blue, G for green and E for black or earthed neutral.

It is quite possible that, as our correspondent states, the supply to which he refers is in fact a three-phase supply and is being wrongly coloured.

D. WINTON THORPE, A.M.I.E.E.

Cause of Motor Overheating.

SIR,—I have a small two-pole motor wound for 220 volts D.C. which is in good condition. I would like to run it on an alternating current circuit 240 volts, to work a small drilling machine. I have had it on circuit and the motor gets hot on no load 15 minutes run. I take it that the increased voltage is the cause. Am I correct? If so, what size and quantity of wire would you advise for rewinding? Will it mean the fields to be rewound, or armature, or both?

Armature dimensions: Length of core, $2\frac{9}{16}$ in.; diameter of core, $3\frac{3}{16}$ in.; 16 slots; 48 commutator segments. Size of wire on armature coils, 23 S.W.G. Brush size, covers 3 segments. Current consumption, 4 amps. approximately.

Allow me to take this opportunity of congratulating THE PRACTICAL ELECTRICAL ENGINEER on the most valuable information it contains. I have found it most useful in the course of my business.

H. (Boston).

The chief cause of the motor heating up is that the field magnet is not laminated.

To remedy the trouble, fit laminations for the field magnet. If you apply to Joseph Sankey & Sons, Ltd., 168, Regent Street, London, W.1, they will send you lists of their laminations, from which you can select the size required.

The increase in voltage from 220 to 240 should not cause appreciable overheating, but will cause a slight increase in the normal running speed.

Utilising Existing Cables.

SIR,—It is desired to connect low voltage distributor cables (unbalanced load) to a three-phase, four-wire supply. The distributors consist of two three-core independent cables as used for D.C. three-wire system, with the neutral conductor of standard section, relevant to the outers for D.C. three-wire.

It is not possible to arrange distribution of the entire load through a single four-core cable as for usual three-phase distribution, and it is desired, as far as possible, to utilise the existing cables.

For three-phase balanced load with the instantaneous algebraical sums of current in, say, red and green being equal and opposite to current in yellow, it would seem that the sectional area of the neutral in each of the two cables in question should be similar in area to either of the two-phase wires, but that as the load is unbalanced, the sectional area of the neutral should in each case be similar in section to phase wires for the most loaded phases in each cable, that is, the neutral in each case should be similar in size to yellow or green.

Is my assumption correct?

J. M. (Plymouth).

THE REGENERATIVE PRINCIPLE APPLIED TO WATER PUMPING PLANT.

Four 1,250 h.p. synchronous induction motors, capable of revolving in either direction at speeds up to 400 r.p.m. without risk of damage, have been supplied by the G.E.C. for driving dry dock pumps at the recently opened extension to the Southampton Docks.

The reason for this special provision is that, should the electrical supply fail, it enables the water in the dock to flow through the pumps and drive the motors, the pumps then acting as water turbines.

Normally, the motors run at 272.3 r.p.m. when operating on a 6,600-volt, three-phase, 50-cycle supply, and are designed for a maximum runaway speed of 400 r.p.m. and an overload of 25 per cent. for two hours.

TWO VALVES IN ONE BULB.

A new valve introduced recently enables users of battery-operated wireless receivers to obtain loud-speaker power performance really comparable with that obtained from mains operated sets. The new Mazda P.D.220 is virtually two valves in one bulb and works on the recently discovered principle known to radio engineers as "Class B amplification."

In spite of the large power output which the new valve gives, its consumption of H.T. current is very economical. It only takes power in proportion to the strength of the signal received. In many battery receivers, its use will actually reduce the total demand from the H.T. battery. The valve costs 14s. and full instructions are supplied with each one.

FIRST IN EVERY RACE.

The remarkable reliability of B.T.H. magnetos has once again been demonstrated. In the T.T. motor cycle races held in the Isle of Man, B.T.H. magnetos were fitted to no fewer than 35 machines out of 45 completing the course. They were on the machines gaining first and second place in every race, all the manufacturers' team prizes, and making record or fastest laps. They also achieved third place in two out of the three races.

An interesting booklet, which gives a full description of the Osram photo cell relay unit and its industrial applications, has been issued by the G.E.C.

END OF VOL. I.

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