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CONTENTS

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The Manufacture of Star-Quad Telephone Cable

J. E. DEERING

Part I.—Quadding and Stranding

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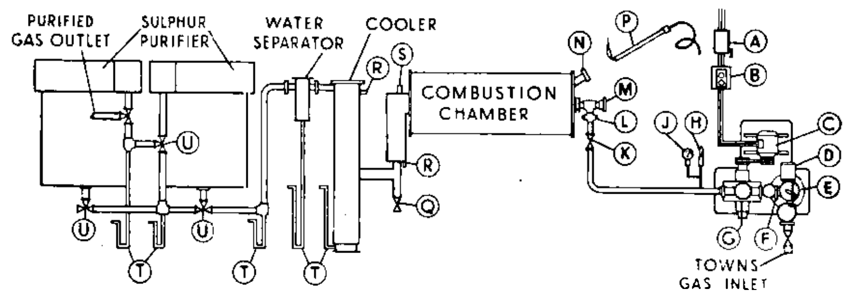
In a series of articles the author proposes to describe the manufacturing processes involved in the production of star-quad cable and the defects commonly encountered during manufacture. The first part deals with the annealing of the copper wire, its insulation and formation into quads and subsequent stranding to form the cable core.

Annealed Copper Conductor.

THE copper from which the conductors of a telephone cable are made passes through a sequence of processes before it finally emerges as wire. Space does not permit these operations to be described and it must suffice to introduce the copper when it has been drawn down into wire of the desired diameter. The process of reducing copper to the size required by cold drawing increases the tensile strength by as much as 11 tons per square inch, giving an ultimate tensile strength of perhaps 30 tons per square inch. Wire of such tensile strength is most suited for overhead line construction, but its condition would render it unmanageable during the processes involved in cable manufacture. Therefore, it must be annealed, whereby the tensile strength is decreased and the ductility increased. The actual annealing process is not a sensitive operation, but the minimum temperature at which the softening commences to occur is influenced by the previous amount of cold working. High purity copper may be partly softened at temperatures below 100° C. if maintained for prolonged periods, but the minimum softening temperature used in practice is usually at least 200° C., a rough and ready guide being to heat the copper until it is at a dull red heat. High temperature increases surface deterioration by scalding, so the usual temperature employed is in the order of 400° C. Fig. 1 shows the change which takes place during an annealing cycle from the hard drawn condition. What actually takes place is that the cold working deforms and distorts the individual crystals or grains, and these distorted crystals are harder and offer greater resistance to further deformation, so increasing the tensile strength. During the annealing, re-crystallisation occurs, new crystals of small size are formed and these tend to grow by absorption of one another. With copper, the rate of growth is not very pronounced and this explains why the annealing of copper is comparatively insensitive to time or temperature effects.

Copper readily acquires an invisible protective film of cuprous oxide which increases by heating at low



A. Switch Fuse for Compressor Motor.
B. Compressor Motor Contactor Push-Button.
C. Compressor Motor Drive.
D. Air Filter.
E. Air-Gas Mixture Control.
F. Air-Gas Mixing Valve.
G. Rotary Mixing Compressor.
H. Pilot Flame.
J. Pressure Gauge.
K. Mixing Throttle Valve.
L. Flame Trap.
M. Burner Sight Glass.
N. Lighting Hole Cap.
P. Lighting Torch.
Q. Blow-off Valve
R. Cooling Water Inlet.
S. Cooling Water Outlet.
T. Water Sealing Traps.
U. Purifier Changeover Valves.

FIG. 2.—SCHEMATIC ARRANGEMENT OF 1,000 CU. FT./HR. EFCO CONTROLLED ATMOSPHERE PLANT.

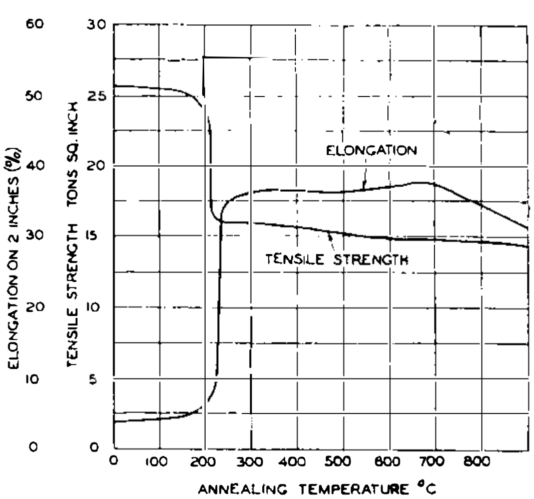


FIG. 1.—GRAPHS ILLUSTRATING ANNEALING CYCLE.

temperature. If, however, the polished wire is exposed to atmosphere contaminated with traces of sulphide it tarnishes, so that the bright surface progressively changes through a series of reddish green and blue tints, to a dull black, typical of cupric sulphide. The rapidity depends upon the sulphur content and humidity of the atmosphere.

To prevent oxidation, wire used in the manufacture of telephone cables is annealed in containers sealed against the ingress of air and filled with a non-oxidising or inert atmosphere, so producing a dry bright annealed wire. A suitable and inexpensive inert atmosphere can be obtained from an equipment designed to use town's gas, or an equipment employing regenerative burnt ammonia. Town's gas is the usual source, and an outline of its purification will be given.

By means of an automatic mechanical mixer (Fig. **2**) a definite ratio of air and town's gas can be maintained at constant pressure. The air/gas ratio employed provides almost complete combustion, the resultant atmosphere being either neutral or slightly reducing and consisting mainly of nitrogen and carbon dioxide, with perhaps small traces of carbon monoxide, hydrogen and sulphur dioxide. After combustion, the resultant gas is passed on to various cooling towers and sulphur purification boxes.

The inert atmosphere thus obtained is introduced into the sealed container housing the coils of wire at a pressure sufficient to purge or displace the air from within. When this is completed, the furnace bell is lowered over the sealed container and the heating cycle commenced. It is customary to have the furnace temperature controlled to prevent it overshooting, which would give rise to stickiness, especially with wire on spools. The temperature to which the control is set, and the time the furnace remains over a charge of wire, depends on the weight of copper to be annealed.

At the completion of the heating cycle the furnace bell is removed and the sealed container is water-sprayed for perhaps 1½ hours, depending on the weight of the charge and type of annealing plant. Fig. **3** shows a typical annealing plant which comprises three hearths, showing the annealed charge on the point of being unloaded; a second hearth awaiting the furnace bell is shown in the centre.

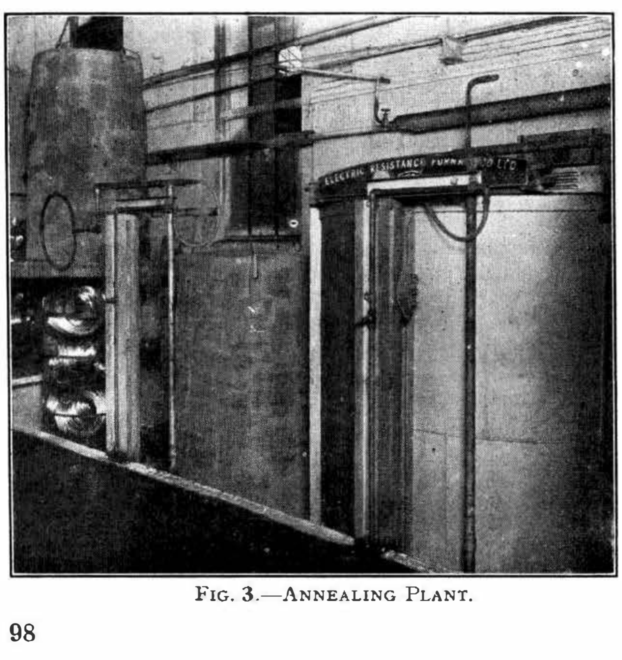


FIG. 3.—ANNEALING PLANT.

The annealed wire used in the manufacture of telephone cables should comply with British Standard Institution Specification No. 128, wherein it defines the term annealed wire as satisfying the following requirement :—

"When a sample wire 10 inches long is slowly and steadily stretched, the elongation without fracture shall not be less than the appropriate value given below."

0·0076 inches diameter and under	15 %
Above 0·0076 to 0·020 in. dia. ..	20 %
Above 0·020 to 0·048 in. dia. ..	25 %
Above 0·048 in. dia.	30 %

Process of Paper Lapping.

The bare conductor is insulated with a lapping of paper tape helically applied with a certain degree of looseness to include air as part of the dielectric.

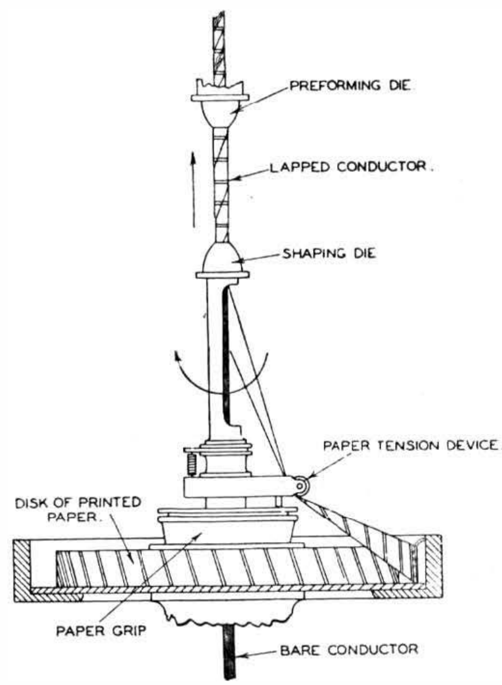


FIG. 4.—ARRANGEMENT OF PAPER LAPPING HEAD.

The helically lapped paper actually forms a self-supporting paper tube, with an internal diameter a little greater than that of the conductor. This means that the conductor has a certain freedom of movement within the tube, but such freedom is liable to cause changeable electrical characteristics. A simple means is usually employed to reduce this freedom and endeavour to ensure a reasonable symmetry. One such method is to use a helical lapping of cellulose paper string applied over the conductor on to which the paper is lapped. This method is usually employed in trunk type cable which specifies closer tolerances than local type cable.

On local type cables the paper tape is usually crimped or wrinkled during the paper lapping process. By this means the wrinkles, plus the double thickness of paper due to the overlap, constitute a support tending to centralise the conductor.

Fig. **4** depicts a typical lapping head for local type cable. A roll of paper printed with identification lines is caused to rotate by a revolving platform and gripping device. The bare conductor passes through the centre of the platform and the paper tape is lapped on to the conductor at the opening directly beneath the die mouth, which is also revolving with the platform. This die shapes the helical lapping to form a paper tube around the conductor. Directly above is a second die having an internal diameter slightly less than the shaping die. The formed tube must, therefore, be crushed to a degree determined by the second or preforming die, which in fact causes the paper to wrinkle. If a length of paper wrinkled in this manner is removed from the conductor it will be seen that the wrinkles are actually lengthwise down the centre of the paper tape. The width of the wrinkled portion of the paper depends on the overlap of the applied tape and occurs where the single thickness passes through the preforming die (omitting the question of texture of the paper). An overlap of 50 per cent. makes the wrinkling excessive, as the paper builds up at intervals behind the die and collapses; an overlap in the region of 30 per cent. is usual. Fig. **5** illustrates this method of wrinkling.

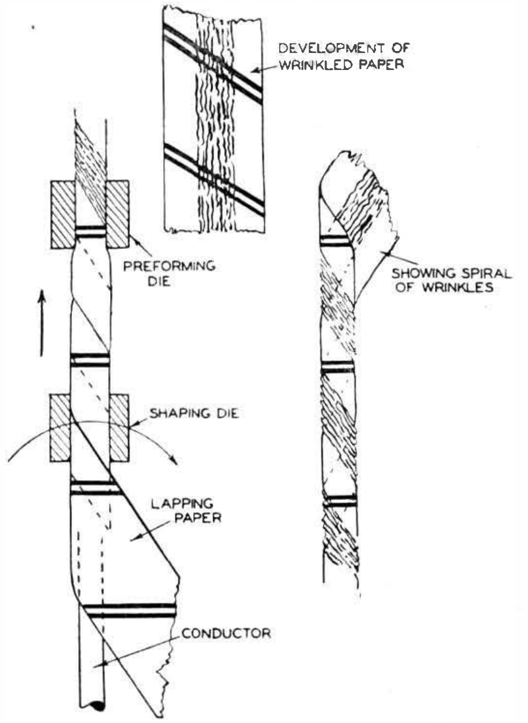


FIG. 5.—WRINKLING DURING THE LAPPING PROCESS.

When a conductor is insulated by either of the above methods, it is reasonable to say that the conductor is situated centrally within a paper tube. The paper should have a uniform texture and be long-fibred and free from any metallic particles and deleterious substance. A strip of the paper one inch wide should be able to support a weight of **4** lb. for each mil. (0·001 in.) of its thickness.

The Process of Quadding.

The single insulated conductor is next associated with three others similarly insulated in such a manner that they remain in a fixed position throughout their length. This process is referred to as quadding. Four insulated conductors are led from their separate bobbins through a die plate and on to a haul-off capstan. The usual principle is for the individual bobbins to float within a rotating cage which is designed to impart a calculated twist effect to the four conductors. The relationship between the speed of the rotating cage and die plate, together with the speed of the haul-off capstan, govern the pitch or length of lay of the quadded conductors.

It is arranged that the four insulated conductors are twisted or quadded around a central cellulose string. This forms a bedding and is designed to increase the symmetry of the quad. The object is to quad the insulated conductors to form a four-point star, and maintain an equal distance between the corners of the star formation throughout the length of the quadded conductors. To maintain the symmetry of the quad the formation is whipped with cotton whipping, which also affords a means of identifying the quad within a completed cable. Fig. **6** shows a typical trunk type quadding machine. The rotating machine is seen at the left of the illustration, with the haul-off capstan situated towards the front, and finally a bobbin to receive the quadded conductors.

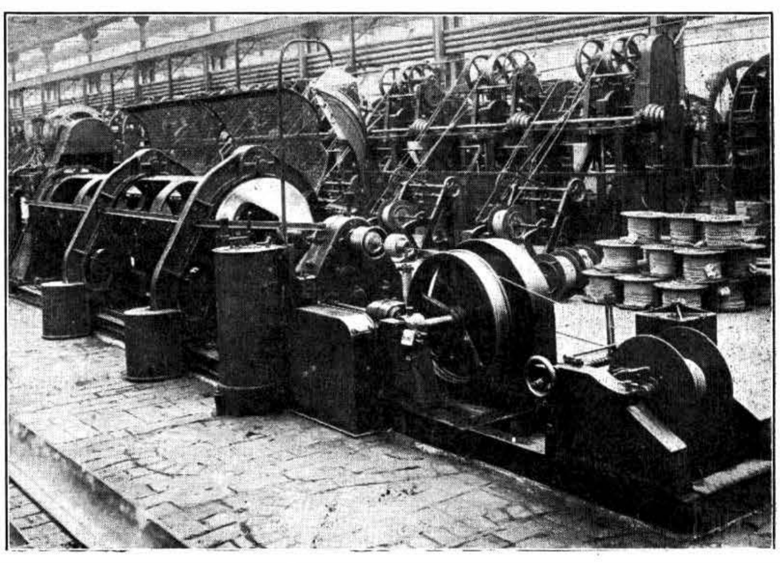


FIG. 6.—TUBULAR QUADDING MACHINE.

In the course of manufacture it is not possible to insulate and quad the conductors so accurately that absolute symmetry exists throughout the entire length, so that a capacitance difference must be expected, and a degree of interference due to capacitance unbalance has to be tolerated. To reduce this as far as possible, not only are considerable pains taken to obtain the maximum degree of symmetry in a physical sense, but care is also taken to balance the electrical properties of the four wires and their insulations as far as possible. Thus to minimise resistance unbalance between the four wires it is usual, especially in the manufacture of trunk and carrier type cables, to arrange for wire from the same coil to comprise the four conductors of a quad. The four selected lengths of wire are associated by means of a tally and these are paper-lapped to comprise the A, B, C and D conductors of a quad. Furthermore, to reduce the probability of interference arising due to dielectric losses or leakance, the four wires selected to constitute a quad are lapped with insulating paper selected from the same roll of paper. Multicoloured paper to distinguish the different conductors is not employed in star-quad cable manufacture. The method adopted is that the paper is so printed with thin ink lines that when lapped around the conductor the lines appear as rings. For the " A " conductor, a series of equally spaced single rings is used, for the " B " equally spaced groups of two rings, and likewise three for the " C " conductor, and four for the " D." The rings are so spaced that an equal amount of ink is used for each conductor, thus equalising any effect the ink may have on the electrical characteristics of the completed quad. To minimise any such effect the ink used is made from analine dye

The Process of Stranding.

This process is an extension of the quadding process whereby a number of quads are laid together to form the centre core and outer layers of the cable. The quadded conductors contained on metal bobbins are mounted around the circumference of a cage (see Fig. 7). Each cage will accommodate the required number of quads for a particular layer of the cable, and in star-quad cable the centre core comprises one, three or four quads, the increase in the number of quads per succeeding layer being six, so each cage will carry six more bobbins of quadded conductors than the previous cage. The bobbins are mounted around the cage in a sequence to comply with the specified colour code of the cable, which is given in Table 1. The

TABLE I

Positions of quad in layer	Colour of wire markings	Colour of cotton whippings	
		Centre and even layers	Odd layers
1st " Marker " quad	Red	White with Orange	Black with Orange
2nd, 4th, etc.	Blue	White	Black
3rd, 5th, etc.	Red	White	Black
Last (Reference)	Blue	White with Orange	Black with Orange

cable core is built up in layers and the stranding direction is reversed for each layer. This means that adjacent cages revolve in opposite directions. Each cage revolves with a die plate through which its quads pass, and the stranding of the particular layer takes place directly following the die plate through a fixed die the size of which controls the overall diameter of the cable core, which has now received an extra layer. The die plate retains each quad in its correct position for the particular layer when stranded. Up to nine layers may be applied simultaneously on the largest machines, but usually not more than seven layers are applied at one time. The distance corresponding to the length of strand formed during one revolution of the cage represents the stranding lay and, as different stranding lays are required for different layers, the cages must revolve at different speeds. Finally, two helical lappings of insulating paper are applied over the core, the outer one being red if an antimony alloy sheath is to be used. The completely stranded cable is drawn off at a constant speed by a large diameter haul-off capstan, from which the stranded core is wound on to a perforated metal drum driven by a friction device or other means to allow for the increase in diameter as it gradually possesses the cable core.

There are two types of stranding machines ; one in which the bobbins are fixed rigidly to the cage

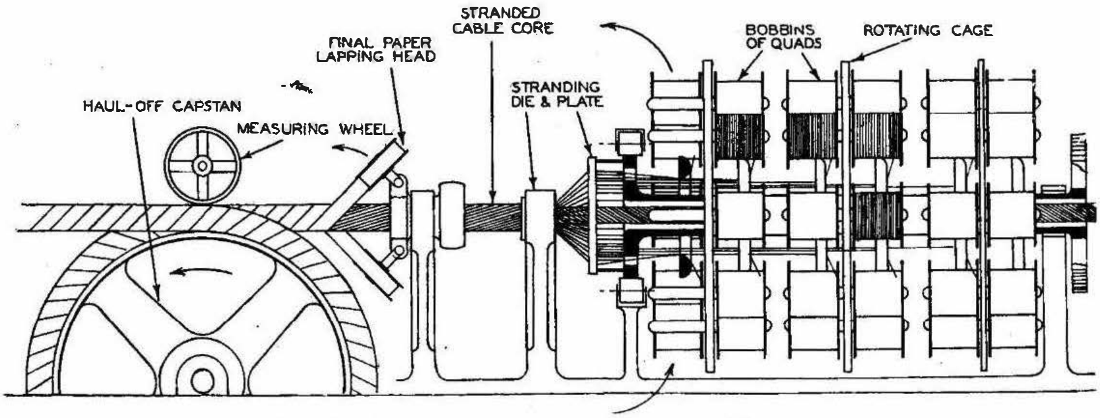


FIG. 7. OUTLINE DIAGRAM OF STRANDING MACHINE.

and the other in which they are free to rotate relative to the cage. It is difficult to assess which is the preferred type, but the relative effects can be summarised.

(1) With the fixed bobbin, the quads are themselves twisted on their own axis, so that the resulting pitch or lay is either increased or decreased according to whether the stranding lay is in the same sense as the quadding lay or not; with the floating bobbin, the lay of the quad is unaltered by the stranding process.

(2) With the fixed bobbin, adjacent quads in the same layer are not twisted with regard to one another, whereas with the floating bobbins they are.

(3) With the fixed bobbin, the quads in any layer are not twisted with regard to any point inside the cable; the converse applies to the floating bobbins.

Screened Pairs.

Some cables contain screened pairs, usually situated in the centre of the cable. The individual screening of these pairs isolates them from the remaining quads of the cable from an electrostatic viewpoint. The screening is by a helical lapping of metallised paper tape, and to ensure that there is no capacitance between any one wire of one pair and any wire of another pair, the metallic screen overlaps where a join in the tape is necessary. The screens are kept insulated from earth when the cable is installed to prevent the circulation of earth currents, liable to cause noise. The tape does not provide any electromagnetic screening so that screened pairs must have different lays from each other and from any surrounding pairs.

Drying.

Following the stranding process, it is often the practice to make a rough test of the core for resistance unbalance, mutual capacitance and capacitance unbalance before the core is dried in readiness for lead sheathing.

It will be remembered that the core is wound on to a perforated metal drum as it is stranded. This drum and its contents are placed in a drying oven to remove all the moisture from the paper and between the layers and conductors, and the perforated drum allows the heat to penetrate freely.

The temperatures of the inside and the outside of the layers in the cable are equalised as far as possible at not more than 135° C.; it is important that the process does not make the paper used in the cable become brittle.

Book Reviews

"Wireless Direction Finding." R. Keen, M.B.E., B.Eng. 1,059 pp. 633 ill. Iliffe & Sons, Ltd. Price 45s.

The popularity of this classic textbook on D.F. is shown by the fact that the present edition is the fourth published since 1922. The 1922 edition reflected mainly the rapid development of D.F. in the 1914-1918 war, the 1947 edition describes not only developments during the era of peace but also those which occurred during the 1939-1945 war. During the latter period the Fighting Services maintained and operated M.F., H.F. and V.H.F. D.F. networks on a considerable scale, and there is little doubt that the earlier editions of "Keen" were of great value to those responsible for the design, construction, operation and maintenance of the D.F. stations. It is to be expected that this new and revised edition will be of no less value to those responsible for D.F. networks for Civil use.

The new material includes sections on the design and testing of H.F. goniometers, on transmission line theory as applied to Adcock aerial systems and on the cause and reduction of resonance effects in Adcock aerials and feeders. The chapter on H.F. D.F. has been re-written and new sections added on the calibration of ship and aircraft D.F.'s. The chapter on radio beacons now includes a description of the U.S. "radio range" system. A valuable section on the statisticaltreatmentof bearings and their classification (due to W. Ross of the National Physical Laboratory) has also been added, together with views on the organisation of a network of H.F. D.F.'s. The chapter on Aircraft Instrument Approach and Landing Systems now includes a description of the system introduced by the (U.S.) Civil Aeronautical Administration and which has been recommended for international standardisation. Descriptions of the Gee, Loran, Decca and Consol navigational aid systems are included.

The style of the book is in general descriptive rather than analytical or theoretical, and the latter aspects of the subject are somewhat inadequately dealt with. This is noticeable for instance in the section dealing with the sensitivity of Adcock D.F.'s where one might expect a theoretical discussion leading to the calculation of the signal-to-noise ratio for a specified field strength. The treatment of the origin, measurement and theoretical analysis of polarisation error does not reflect the recent advances in this subject and the important "Heiligtag" (wave interference) effect is dismissed rather summarily. However, the book may be confidently recommended to those dealing with the more practical aspects of D.F.

W. J. B.

"The Vector Operator j." F. C. Gill, A.M.I.E.E., A.M.I.Mech.E. 66 pp., 32 ill. Pitman 7s. 6d.

The author states that the book has been written to explain the conception of the j operator and to indicate the method of applying it and has endeavoured to carry out this rather difficult task in an elementary manner. The first chapter describes the method of representing a vector quantity in Cartesian co-ordinates using the j operator and is followed by examples of simple calculations of single- and three- phase circuits and systems. Finally a description of the use of the operator in polar co-ordinates is given together with a few simple proofs.

The general treatment is quite good and interesting but there is nothing novel in either the method of approach or in the conclusions. The book is written entirely from the power engineer's point of view and it should prove of use to the student of this subject who has not had the advantage of a proper course in mathematics. It cannot, however, be wholeheartedly recommended to the student of telecommunications engineering whose requirements and application of the j operator are generally of a different and perhaps more precise nature.

J. R.

The Introduction of Manual Switching of Teleprinter Circuits in the Public Telegraph Service

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C. W. A. MITCHELL, A.M.I.E.E.

U.D.C. 621.394 : 621.394.3

Part 2—The Switching Equipment

The previous part of this article stated the reasons for the introduction of manual switching in the Public Telegraph Service and described the switching network and the programme of conversion. This part describes the switchboards and associated apparatus employed.

Signalling Principles.

THE standard form of teleprinter circuit used for the public service employs double current signalling on a two-wire, bothway simplex basis. Local copies of transmitted messages are not required and simultaneous communication in both directions of transmission is therefore possible and is, in some circumstances, used. The switching apparatus is designed exclusively for use with circuits of this type, and Fig. 1 is a skeleton diagram showing a typical office-to-office connection via a switchboard.

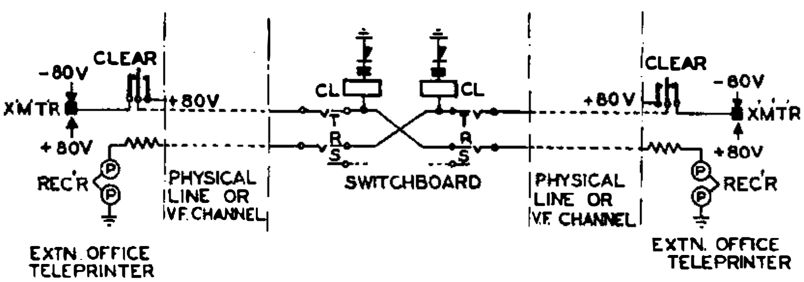

FIG. 1.—SKELETON DIAGRAM OF THROUGH CONNECTION.

Following the precedent set by the D.T.N. the line signalling arrangements constitute what may be termed a pulse signalling system. This system is based upon the maintenance of marking (−80V battery) conditions, corresponding to the " rest " condition of the teleprinter, on the line at all times except when engaged in calling, teleprinting, or clearing, each of which operations is effected by transmitting one or more spacing signals. The signalling conditions in each condition are :—

(*a*) *Calling*. A series of spacing impulses is transmitted by operating the keyboard of the calling teleprinter. Any combination of signals will suffice, but it has been found convenient, for operating reasons, to use the code of the wanted office as, for example, BM BM BM repeated continuously until attention is given by the switchboard operator. The space bar is depressed once after each repetition of the code and the whole transmission should be smooth and continuous.

(*b*) *Teleprinting*. Normal teleprinting conditions, as on point-to-point circuits.

(*c*) *Clearing*. Clearing is initiated by sending a long spacing signal to line and is effective on restoring to the marking condition at the end of the clearing signal. The clearing signal is applied by a lever key either of normal type or incorporating a mechanically timed release.[1] The length of the signal should be at least three seconds to ensure satisfactory clearing under all line conditions, and operators are instructed to hold the key operated (where ordinary lever keys are used) for five seconds. Mechanically timed keys are adjusted to a release period of five seconds.

The Teleprinter Extension Circuit.

The Teleprinter No. 3x, which is in general use in the inland telegraph service, is also used on manually switched circuits. This machine has an answer-back attachment which is operated electromagnetically from contacts on the receiving bellcrank corresponding to the secondary of letter A. A paper failure alarm device has also been developed for use with teleprinters used for manual switching, as a safeguard to traffic received on positions which are not staffed on a full-time basis.

The answer-back signal is used, primarily, to verify connection to the correct office at the beginning and end of each message and permits messages being received on unattended teleprinters. It is also used in conjunction with the paper failure alarm as a warning to the sending operator that a paper fault has occurred, the circuit being arranged so that answer-back signals are transmitted by the faulty teleprinter so long as the paper fault persists. A calling lamp is provided on each position and is arranged to remain alight after an incoming call until it is reset by a key. A key is also provided to facilitate attention to paper faults and the clearing signal is transmitted by a separate key as already mentioned. The circuit arrangement of an extension office teleprinter is shown in Fig. 2.

On connection of an incoming call the WRU contacts close due to the caller sending the " Who are you ?" signal and the answer-back electromagnet AB1 operates to the charging surge in condenser QA. During the consequent transmission of the answer-back signal, contacts AB1 close and operate the calling relay L which holds to a contact of the reset key. The calling lamp glows until reset by the operator attending to the message.

On outgoing calls, the operator calls the switchboard, using the teleprinter keyboard as already

[1] *P.O.E.E.J.* Vol. 38, p. 16.

described, and the local calling lamp circuit is not operated. The call is terminated by sending a long spacing signal by the clearing key.

When a message is being received, the paper alarm contacts PF close during each character for approximately 60 milliseconds. Relay P, which is made slow-to-operate by condenser QB, does not respond to these impulses from the PF contacts. In the event of a paper fault, however, the contacts close for at least 150 milliseconds so that relay P operates, causing a relief relay PF and the answer-back electromagnet also to operate. Relay PF locks in the operated position and applies earth to start a flicker pulse generator while also connecting the calling lamp to the flicker pulse. The lamp flashes until attention is given and an audible alarm in the instrument room is operated from the pulse generator.

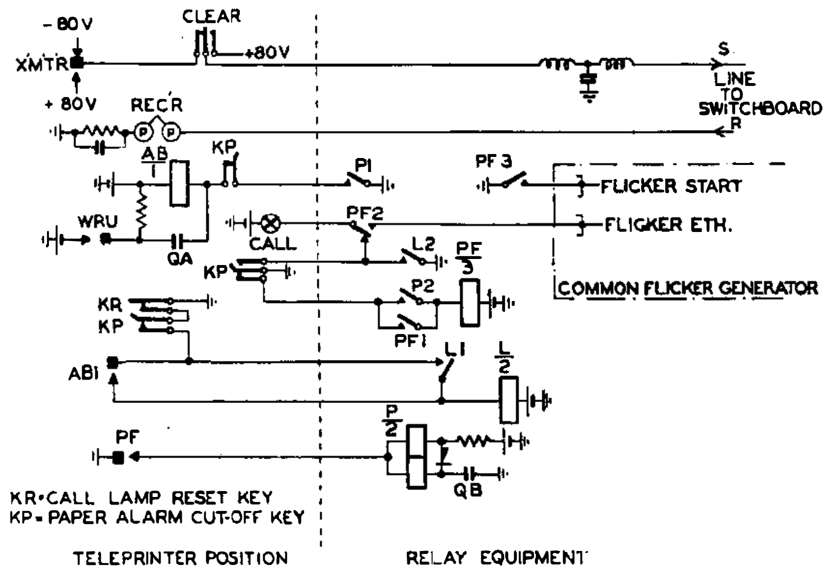

Fig. 2.—Extension Office Teleprinter Circuit.

The answer-back mechanism operates so long as the PF contacts on the teleprinter remain closed and, with a transient fault, the sending operator may proceed with the message when the answer-back signals cease. With a persistent fault, the operator attending to the faulty machine can cut off the alarm conditions by operating the " Paper Alarm Cut-off " key and, the answer-back mechanism having stopped, can advise the caller of the action to be taken. Normally, calls are held and the fault cleared, to minimise risk of duplication of messages.

Switchboard Line Equipment

Provision is made at the switching centre for the following types of line termination :—

(*a*) Incoming teleprinter extension
(*b*) Outgoing teleprinter extension
(*c*) Bothway teleprinter extension
(*d*) Incoming inter-switchboard circuit
(*e*) Outgoing inter-switchboard circuit

Incoming and Outgoing Teleprinter Extension Circuit.

A universal form of line equipment, the circuit of which is shown in Fig. 3, is used for these circuits. The relay apparatus is mounted on a 6 ft. 6 in. rack, 1 ft. 8½ in. wide, which caters for 60 lines ; a typical line rack is shown in the background of Fig. 4. Each rack is provided with fuse mountings for the 6V power supplies to the calling and F.L.S. lamps, and for the 80V supplies to the relays. Connection strips are provided behind the rack for the F.L.S. strapping for groups of outgoing circuits and for common service cabling. The cabling from the I.D.F. terminates directly upon the relay panels.

Separate multiples are provided on the switchboard for incoming and outgoing circuits, the jumpering on the I.D.F. to the line equipment being varied, as indicated in Fig. 3.

The calling relay L, which is effective only on incoming circuits, is polarised by a metal rectifier so that it responds only to spacing (+80V) signals. It provides a loop across the line wires so that the caller receives his own calling signal until a plug is inserted at the switchboard, when the loop is disconnected by the E relay.

Bothway Extension Circuits.

Bothway working is restricted in application to enquiry circuits and to instrument room speaker circuits. The requirements do not warrant the provision of a special rack of line equipment and are met by local modifications to existing incoming and outgoing equipment.

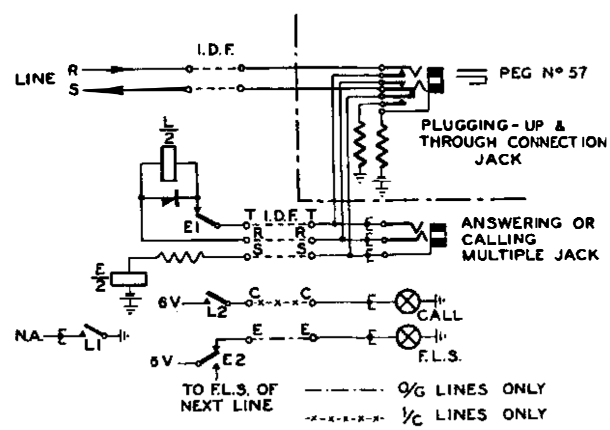

Fig. 3.—Extension Line Circuit, I/C and O/G, showing Connection of Plugging-Up and Through Connection Jack.

The principal addition to the circuit of Fig. 3, apart from the fact that both calling and F.L.S. lamp circuits are jumpered on the I.D.F., is a slow-releasing relief relay for relay L which steps forward the F.L.S. signal on receipt of a calling signal, the release lag of the relief relay being sufficient to mask any intermittent operation of relay L which may occur during normal calling.

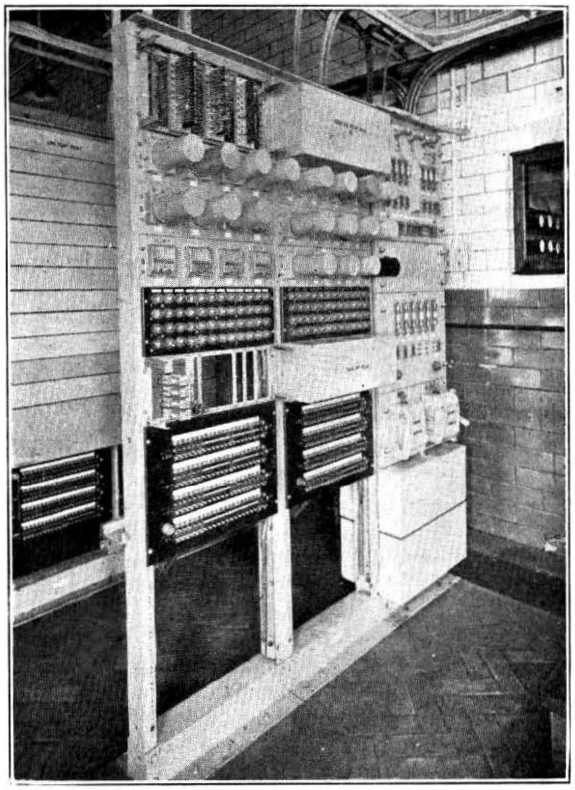

FIG. 4.—SWITCHBOARD, TELEPRINTER 17B—RACK MOUNTED EQUIPMENT.

One bothway circuit occupies the rack space for two unidirectional circuits.

Inter-Switchboard Circuits.

Inter-switchboard junction circuits are routed on V.F. telegraph channels. Calling arrangements are similar to those used on teleprinter extension circuits, and it is normal practice for the calling extension, when extended on a junction circuit by the first switchboard, to resume calling by transmitting the code of the wanted office. The calling relay of the inter-switchboard circuit, as shown in Fig. 5, is also

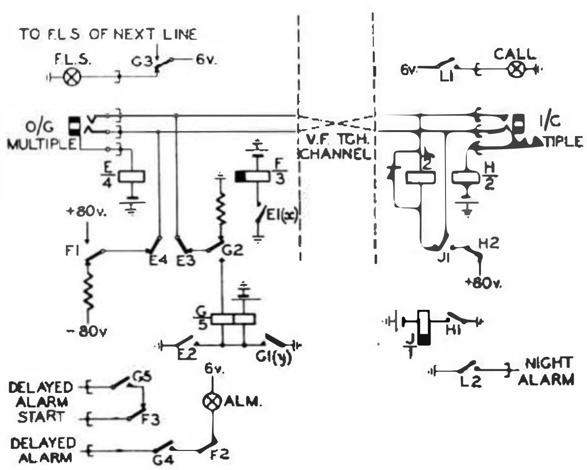

FIG. 5.—INTER-SWITCHBOARD CIRCUIT, I/C AND O/G TERMINATIONS.

looped between the S and R wires so that the caller again receives the calling signal until the distant switchboard operator answers the call.

Although the design of the system provides for through clearing and the supervisory lamps at both switchboards commence to glow virtually simultaneously, it cannot be ensured that both operators will clear down the connection at the same time. It is necessary, therefore, to provide extended engaged facilities so that the F.L.S. at the outgoing end does not indicate a free circuit until the plug has also been withdrawn at the incoming end.

At the outgoing end of the circuit relay G is operated and locks via its own contact when the operator inserts a plug on setting up the call. At the same time, the slow releasing relay F is operated and remains under control of the sleeve relay E. If, when the call is cleared, the incoming operator breaks the connection first, a loop is applied to the S and R lines at the incoming end via the calling relay L. When the outgoing operator then withdraws the plug relay E releases and applies +80V to the S line via contact F1. The positive signal so transmitted passes round the loop at the incoming end and returns to the line winding of relay G which is connected so that the flux produced neutralises that due to the holding winding and causes the relay to release. The release of relay F restores the normal −80V condition to the line and prevents the calling relay at the incoming end from remaining operated.

If the outgoing operator is the first to clear the connection, the testing signal pulse generated by the combined action of relays E and F cannot return since no loop exists at the incoming end of the circuit. Provision is made at the incoming end, by relays H and J, for a pulse to be sent back to the outgoing equipment when the plug is withdrawn from the jack. Relay G is then released and the F.L.S. marks the circuit as free.

A delayed alarm operates after three minutes if, for any reason, an outgoing equipment is not fully released in this period. Such conditions, apart from abnormal operating delays, are indicative of line faults and require investigation.

The relay equipment is mounted on racks similar to those used for extension line relays (Fig. **4**), each rack accommodating 24 incoming and 24 outgoing circuits. The alarm lamps for outgoing circuits are mounted centrally on the relay panels.

SWITCHBOARD POSITIONS

It will be seen from Fig. **6** that the switchboard positions follow telephone practice except that, to accommodate the operator's teleprinter, a special arrangement for the key shelf has been incorporated. The teleprinter is mounted on a sliding shelf, which, when pulled forward, facilitates maintenance. The construction is essentially the same as for the floor mounted, multiple type switchboards employed for the D.T.N. in suites ranging from 2 to 25 operators' positions and with multiples from 70–540 lines; hence, flexibility being a major requirement, each position is of unit construction.

The overall dimensions of each position are 2 ft. 5 in. wide, 3 ft. 3 in. deep and 6 ft. 6 in. high.

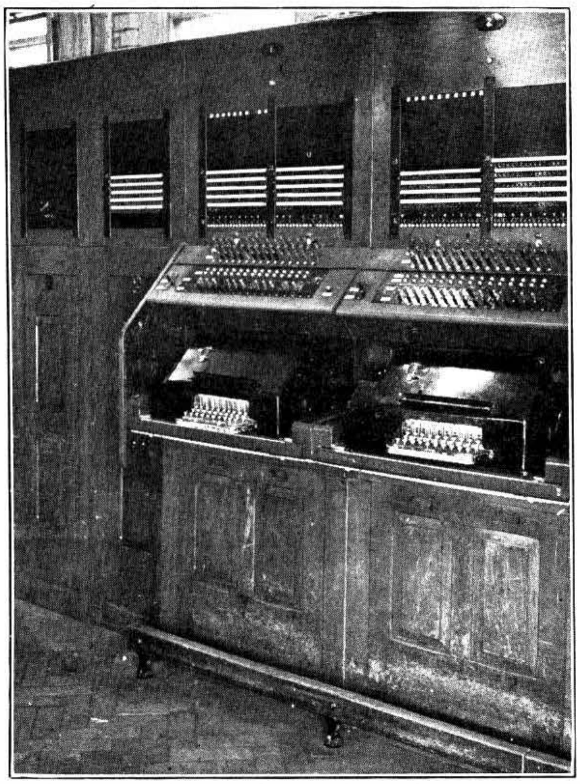

FIG. 6.—FRONT VIEW OF SWITCHBOARD, TELEPRINTER 17A, WITH DUMMY END POSITION AND C.T.S.

In addition to the items of equipment visible in Fig. 6, and subsequently described, the switchboards contain a framework at the rear on which are mounted the 75 cord circuit relays and 9 position relays, together with associated rectifiers, condensers and resistors. Chain supported multiple cable bearers are provided at the rear of the jack field, together with a cable rack for supporting miscellaneous cables, and a connection strip to facilitate their termination. Signalling earth, lamp return and rack earth bus-bars are also provided on each position.

Multiple and Face Equipment.

Two jack panels, each 14 in. high and 10 $\frac{9}{16}$ in. wide, are provided on each position. Separate answering and outgoing multiples are employed, the multiple repetition of the former being 12-panel, and of the latter 4-panel. The answering multiple is arranged on the bottom strip of each panel, the calling lamps being below each strip of 20 jacks, and the designation strip (and labels) above. A spacing strip is then inserted between this and the outgoing multiple, in which each strip of 20-line jacks has the associated combined F.L.S. lamp and designation strip above it. The positions shown in Fig. 6 are equipped for 240 incoming and 380 outgoing lines. A miscellaneous jack strip, multipled over every three panels, provides for test facilities.

The white opal lamp mounted over the centre style bar on each position provides a visual "night alarm" indication of an incoming call, or clearing signal on an established connection. The two red opal lamps mounted centrally beneath each jack panel, and designated "engaged" lamps, provide a visual alarm that the operator has over-plugged an already engaged line, and should take down the connection.

Keyshelf.

The sloping keyshelf contains 15 cord circuits, each consisting of an answering and calling cord, with associated supervisory lamps, and "PRINT/MONITOR" cord circuit key. An "ANS./CALL" key, which is individual to each position, but common to the 15-cord circuits, is mounted on the left-hand side of the key shelf, and a position "CLEAR" key of press button type is mounted on the right-hand side.

Position Teleprinter.

The teleprinter mounted below the keyshelf is the standard B.P.O. Teleprinter No. 3, the electrical connections to which are made by standard plugs and cords on the instrument to a power socket and switch and instrument jack, mounted on the vertical panel at the rear of the sliding shelf.

The teleprinter tape is illuminated by a special lighting fitment mounted on the teleprinter and beneath the teleprinter cover, thus focusing the light on the printing and eliminating any glare to the operator.

Cord and Position Circuits.

These circuits, which are illustrated in Fig. 7, are closely related and are best considered together. Special arrangements have been made to prevent interference with established connections due to accidental overplugging or the duplicate answering of calls in the answering multiple. To ensure this, the tip and ring conductors of all cords are disconnected when the cords are not in use and they remain so until a testing relay in the sleeve circuit has verified that connection is being made to a disengaged line. Relays SA and SC perform this function for the answering and calling cords respectively and test for a 2500-ohm battery on the sleeve conductor of a free line. If this condition is met, the sleeve relay operates in series with the E relay of the line circuit and applies earth to the sleeve conductor via its low resistance holding winding. The sleeve potential is thus lowered so that no other cord could switch to the engaged line should a plug be inserted elsewhere in the multiple. Any attempt to overplug is therefore ineffective and harmless.

While the SA and SC relays afford adequate protection, in this way, against the overplugging of established connections, it is possible for two such relays to operate and hold in parallel if the plugs were inserted into the multiple jacks simultaneously. This cannot readily be avoided in the design of the sleeve relays themselves and, to prevent such a condition from being maintained, common relays are provided in the position circuit which apply a differential current to the high resistance windings of the sleeve relays for a short interval after a plug has been inserted. This current is insufficient to de-flux a sleeve relay which has switched to a free line but ensures the release of any sleeve relay which has operated in parallel with another. In Fig. 7 it will be seen that the sleeve relays derive their

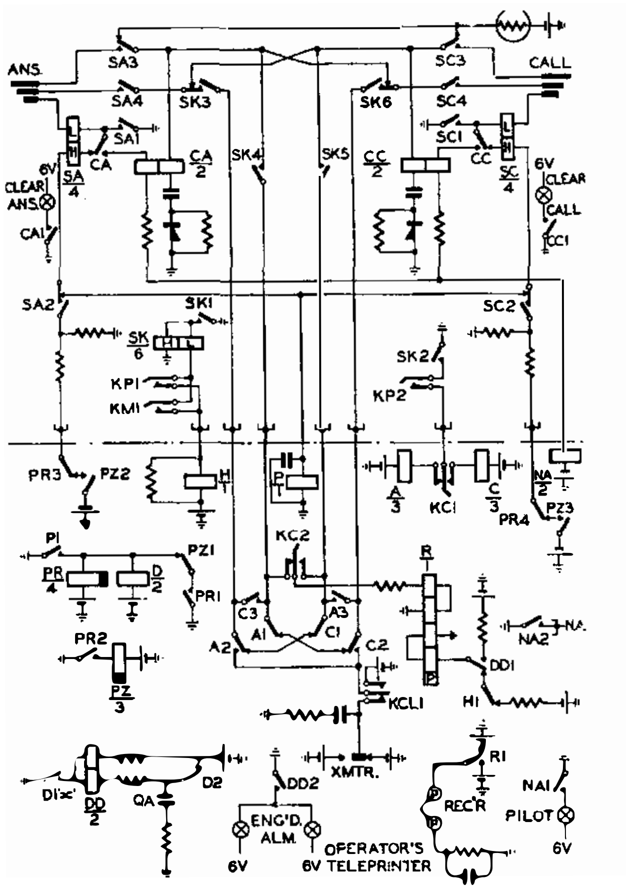

FIG. 7.—CORD AND POSITION CIRCUITS—SWITCHBOARD, TELEPRINTER 14A.

operating earth via relay **P** in the position circuit. Relay **P** is sufficiently sensitive to operate whenever a plug is inserted, whether the line be free or engaged, and it releases when the sleeve relay operates. Relay **P** controls relays **PR** and **PZ** which, on release of P, apply battery, during the release lag of relay PZ, to the high resistance coils of all operated sleeve relays. Sleeve relays which are released in this manner immediately attempt to re-operate and, owing to the inherent differences in the relay timings of the two cord and position circuits involved, one of them gains sufficient lead after one or two testing cycles to prevent the second sleeve relay from operating.

The unsuccessful connection is indicated to the switchboard operator by an alarm. Relay **P** remains operated until the plug is withdrawn, since in this case the sleeve relay has not operated and disconnected relay **P.** Relay DD then operates with a delay of approximately one second, due to the effect of condenser QA. Relay DD causes the operator's teleprinter control relay R to apply spacing conditions to the teleprinter receiver which " races " and feeds out tape. An alarm lamp is also illuminated beneath each jack panel on the face of the switchboard. This combination of alarm conditions cannot readily be overlooked by an operator and is maintained until the ineffective plug is withdrawn, thus allowing the position relays to restore to normal. The delay imposed by relay DD is necessary to prevent a premature alarm being given during normal functioning of the sleeve relays.

When the " Print " (KP) or " Monitor " (KM) key of a cord circuit is operated, relay SK operates and extends the tip and ring conductors of both cords via the position circuit. The SK relays are arranged, in the well-known manner, so that one only can be operated at a time, other cord circuit keys being rendered temporarily ineffective.

Relay H in the position circuit operates in series with the SK relays and removes a holding current from the operator's teleprinter control relay R, leaving this relay free to respond to the conditions applied via the cord circuit tip conductors.

The position " Ans./Call " key (KC) is connected normally in the " Answer " condition so that relay R responds to conditions on the tip conductor of the answering cord. In this position the key also provides for operation of relay A in the position circuit if a cord circuit key is operated to " Print." Relay A in operating applies a loop to the tip and ring conductors of the calling cord so that an extension operator who might be connected would receive her own signals as an indication that the through connection had been interrupted. The tip and ring conductors of the answering cord are connected to the switchboard teleprinter receiving relay and transmitter respectively so that the operator is in teleprinting communication with the party connected via the answering cord.

If the position key KC is operated to the " Call " position relay A in the position circuit releases and relay C operates. The conditions on the cord circuit are thereby reversed, the switchboard operator being in communication via the calling cord and a loop being applied on the answering cord.

To monitor an established connection the cord circuit key KM is operated to " Monitor." Relays SK and H operate as before, but relays A and C remain unoperated. The connection is thus diverted, without interruption, via the position circuit and the operator's teleprinter control relay R is connected in leak on the tip conductor of the answering or calling cord according to the operation of the " Ans./Call" key associated with the position circuit. The operator can, therefore, monitor either direction of transmission without interrupting the call.

A clearing supervisory relay (relays CA and CC) is connected in leak with the tip conductor of each cord, the leak impedance being sufficiently high to have no appreciable effect upon the normal transmission of teleprinter signals. The line coil of each clearing relay is connected in series with a condenser and a metal rectifier. The rectifier is shunted by a resistor so that its effective resistance in the backward or non-conducting direction is controlled within comparatively close limits. When the cord circuit is idle and, apart from short signalling impulses during teleprinting, when it is in use on a connection a negative potential exists on the tip and ring conductors. The clearing circuit condensers are normally charged, via the forward resistance of the metal rectifiers, to this negative potential. When, during teleprinting, the negative potential on the line conductors is replaced by a corresponding positive one the charge on the condenser tends to become reversed but can only do so via the backward resistance of the metal rectifier and its shunt. The time constant of the circuit is such that the energy which can be stored in the condenser in this way during normal signalling can never reach a value sufficient to operate the relay. The clearing signal of five seconds' duration, however, ensures that the charge on the condenser becomes reversed to the full applied positive potential and, on restoration of the normal negative potential when the clearing key KCL is released, the charge again reverses and produces a rapid surge of current in the relay, via the low forward resistance of the metal rectifier. The clearing relay operates to this surge and holds via its own contact under control of the sleeve relay. The supervisory lamp glows and all relays release when the plugs are withdrawn.

The potentials available at the cord circuit for operating the clearing relays depend upon the actual voltage of the nominal 80+80 volt supply at the extension offices and upon the total resistance of the sending and receiving lines and instrument terminations. The components of the clearing circuit have been chosen to ensure satisfactory operation on lines up to 1,200 ohms single-wire resistance, using the standard line terminating circuits for teleprinters and V.F. channels and with telegraph supply voltages of 75V or over. At the same time, a safe margin is provided against false operation to teleprinter signals even on lines of zero resistance and with telegraph supply voltages up to 92V. By suitable choice of components a compact design has been achieved in which the size of condenser is reduced to $2\mu F$ from the value of $10\mu F$ required on previous circuits of this type.

C.T.S., C.S.S. and Dummy Positions.

A universal type section, which can be used for cable turning, cable storing or as a dummy position when required for an additional panel to complete a multiple repetition, has been developed for use with switchboards of the type described and with D.T.N. type switchboards. It is shown in use for two of these functions to the left of Fig. 6 and may be utilised without modification, other than in assembly on site, for either end of a suite of positions.

The "Night Alarm" key, by which the night alarm bell is brought into operation, is normally mounted in the panel of the C.T.S.

AUXILIARY APPARATUS

Plugging-Up and Through Connection Panel.

All lines are routed to the switchboard via the P.U. and T.C. panel on which they appear in conformity with the switchboard multiple layout. The panel is used to provide the following facilities :—

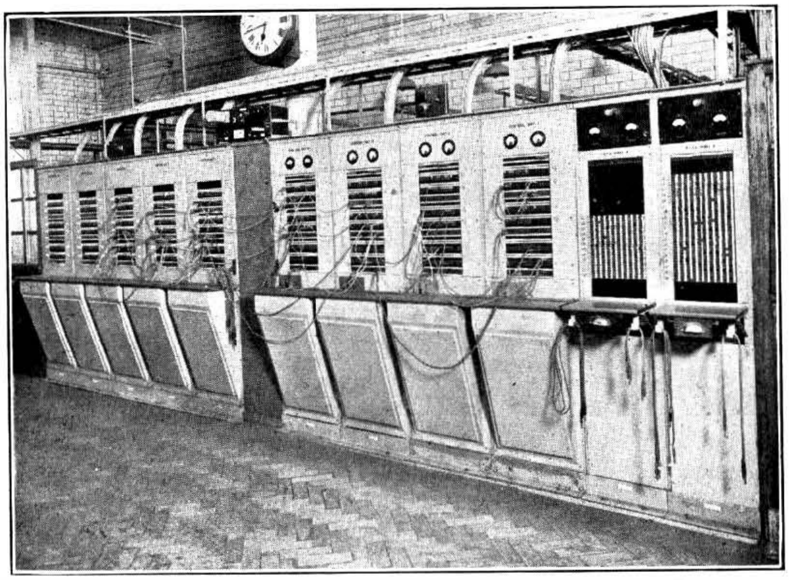

FIG. 8.—PLUGGING-UP AND THROUGH CONNECTION PANELS AND CONTROL BOARDS.

(*a*) By the insertion of a Peg (No. 57), for plugging up faulty circuits.

(*b*) By the use of double-ended cords, for establishing "through-connections" between any two lines, thus relieving the switchboard of long duration plug and cord connections.

(*c*) By the use of double-ended cords, measuring the send and receive line currents on the test milliammeters located at the top of the panel.

With any of these functions, the lines are disconnected from the switchboard equipment, and the multiple jack positions automatically marked as engaged.

A typical installation is shown to the right of Fig. **8**, and the circuit connections in Fig. **3**, from which it will be seen that all lines are routed through this panel before connection to the switching equipment.

The position of the P.U. and T.C. panel in the switchroom is largely influenced by the routes available for the main cable runway between the switchboard and the I.D.F.

Common Equipment Rack.

Mounted on this rack are the position control relays and associated Bulbs, Resistor No. 11 for 12 switchboard positions. Fig. **4** shows two of these racks in the foreground, from which the location of these items will be clearly seen. The alarm type fuse mountings provide 80+80V supplies to the position relays in the switchboard as well as to the rack mounted control relays; also 6V lamp supply for the position and cord circuit supervisory lamps. The relay panel located centrally mounts the rack fuse alarm relays, although as employed with the initial installations all fuse alarm relays were centralised on these panels. The connection strips at the top of the rack facilitate the connection of cables to the switchboard.

Power Distribution and Fuse Alarm Racks.

This rack serves a dual function, primarily for power distribution, but also for the centralised fuse alarms for the switching equipment, and is shown to the right of the common equipment racks in Fig. 4. The cartridge type 80+80V distribution fuses are mounted on the top panel, and the 6V cartridge fuses on the centre panel, together with associated individual alarm type fuses. Alternative sources of power for supplying the 6V A.C. to the switchboard lamps, namely 200–250V A.C. mains, and 230V A.C. standby, are fed to the operative transformer via a mains on/off switch and a triple pole change-over switch. The duplicate transformers are rack mounted, and enclosed in the covers seen at the foot of the rack.

The "No Volt" fuse alarm and exchange urgent and non-urgent alarm relays are panel-mounted at the rear of the rack.

Speaker Signalling Arrangements.

Direct speaker circuits equipped with speaker signalling sets have been in use between V.F. telegraph control boards in instrument rooms since the inception of V.F. telegraph working. The advent of the manual switching system made it necessary to provide, in addition to the speakers still required for the maintenance of point-to-point circuits, for connections between the control boards and the manual switchboards. In this way the retention of separate speaker channels on a number of routes was avoided with a consequent gain in channels available for traffic. The speaker equipment existing on the control boards was, however, unsuitable for use on the manual switching network and a new design was necessary. Since the use of two different forms of signalling would have caused confusion it was decided to convert all speaker sets throughout the country to the new design, whether or not direct connection with the switching network was involved. The new speaker signalling set comprises calling, cut-off and clearing relays similar to those used on the Switchboard, Teleprinter No. 17A.

Cord Circuit Tester.

For routine testing purposes and as an aid to the clearance of faults, a portable cord circuit tester is provided at each switchboard installation. The tester provides for continuity tests of the plugs and cords and their associated cord circuit wiring and relay contacts, continuity being observed on a milliammeter. "Shake" tests of cords are made while observing the milliammeter which reveals intermittent faults due to worn cords. The tester also provides for limiting tests for the clearing relays which must not operate under short line test conditions with clearing signals under 300 milliseconds and must operate under long line test conditions with clearing signals of three seconds duration. Clearing signals for short line tests are timed by a standard telephone dial and can be applied in increasing steps of 100 milliseconds per numeral dialled. The 300 millisecond test signal is produced by dialling 3. Long line tests are made, using a lever key, the operation of which is timed by a stop watch. The tester is used by the traffic staff for day-to-day routine functional tests and by the engineering staff when dealing with faulty or suspected apparatus.

Conclusions.

The introduction of manual switching to the Public Telegraph Service has radically changed the method of handling telegraph traffic, and has proved very successful in practice. It must be emphasised, however, that at its inception it was introduced as an emergency war measure, and that at no time has it been out of mind that it is but a temporary method for the more efficient handling of telegraph traffic under the deconcentration conditions resulting from the war, and that, with the introduction of automatic switching, at present under active development, this phase in the metamorphosis of traffic handling will disappear.

Opportunity has been taken to mention the various factors which have influenced the finalised design of the switching equipment now installed at all centres since the experience gained may be of interest and value to others concerned with the manual switching of teleprinter circuits. It should be stressed that without the closest co-operation between the engineering and traffic interests, the experience gained with the initial installations during the war could not have been turned to advantage so speedily as proved to be the case. In this connection, as well as for information contained in this article, the authors wish to acknowledge their indebtedness to Mr. E. W. Cross, of the Telecommunications Departmert, Inland Telegraph Branch.

In conclusion, a development and conversion programme of the nature described could not have been successfully handled without close co-operation between all parties involved, including Headquarters, Regional and Area staffs. Thanks are also due to colleagues in the Telegraph Branch of the Engineer-in-Chief's office for assistance given in the preparation of this article.

Through-Group Working in the Coaxial Cable Network

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U.D.C. 621.395.44 621.395.5 621.392.52

Part 2—The Complete Installation Performance Characteristics, Installation Details

The transfer of circuits from one coaxial system to another via through group filters involves the translation of the H.F. signals to the basic group range of frequencies at each point of transfer. When several systems are to be linked the small irregularities in frequency response introduced at each stage of translation may be cumulative and necessitate group equalisation

Performance of Coaxial Translating Equipment

THE performance of equipment other than through group filters has not so far been discussed. When it is recollected that in the transmission path of each group extended over the two coaxial systems in tandem (shown diagramatically in Fig. 1), and reduced to audio frequency at each end, there will normally be no less than four sets of group translating equipment and four sets of supergroup translating equipment, incorporating filters, modulators, attenuator networks, amplifiers, hybrid coils and transformers, as well as the two coaxial lines and the through group filter, it is clear that the requirements of each individual link in the chain may well be stringent. This is particularly true of the permissible variation with frequency of the transmission loss in the group range of frequencies or "group spreads."

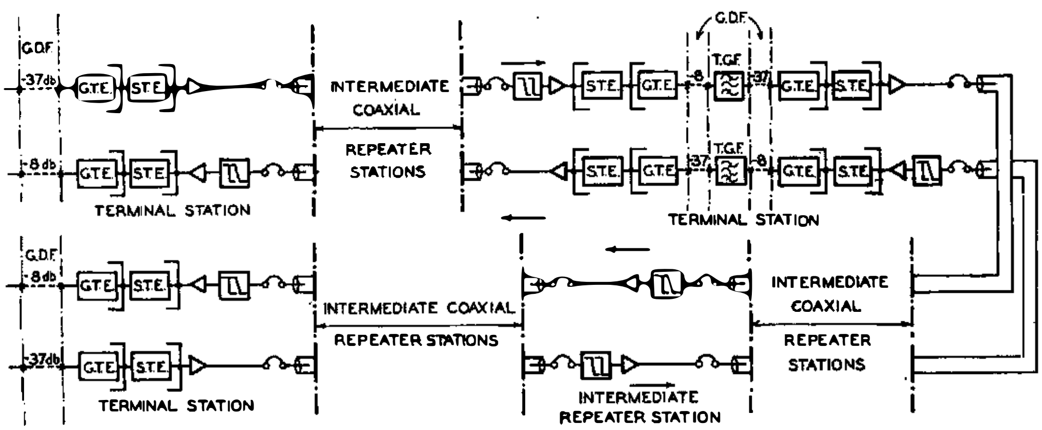


FIG. 1.—ONE THROUGH GROUP ON TWO COAXIAL ROUTES IN TANDEM.

In a group extended over one coaxial system and a 12-channel line as shown in Fig. 2 the equipment includes two sets of group and supergroup translating equipment, two sets of group modulating equipment and the two lines.

Group Spreads.

The group spread of a transmission path may be defined as the difference between the maximum

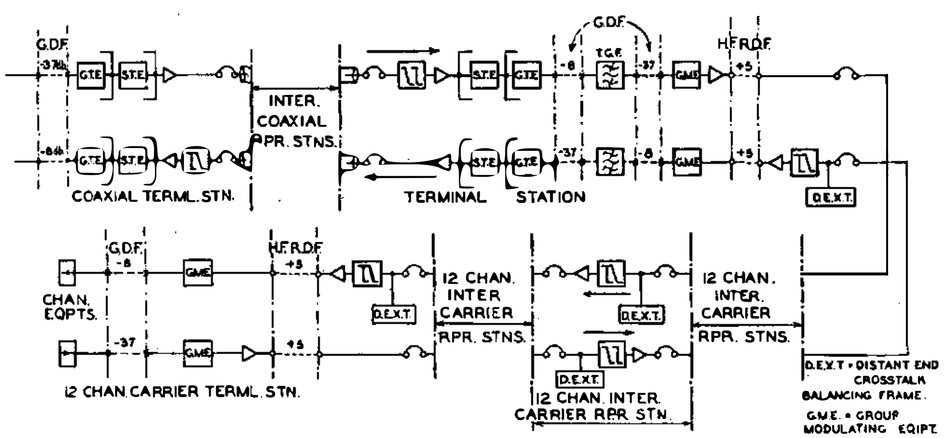


FIG. 2.—ONE THROUGH GROUP ON A COAXIAL AND A 12-CHANNEL CARRIER ROUTE IN TANDEM.

and minimum insertion losses of the path measured over a range of frequencies corresponding to side-bands of the particular group concerned. The maximum permissible spread measured between the G.D.F.s at which the group terminates before being translated to audio frequency is determined by the range of sideband levels which can be accepted by the translating or channel equipment consistent with meeting the overall audio-to-audio transmission requirements. The maximum permissible spread at intermediate points as decided by noise and crosstalk considerations is, in general, greater than can be tolerated at the terminals of the types of channel equipment now in use. The standard P.O. No. 7 type channel equipment is designed to cater for input sideband levels down to 3 db. below the group line-up (mid-band) frequency. Since the frequency distortion characteristic of the group may well be roughly symmetrical about a peak or trough at the line-up frequency, the figure of 3 db. should also be taken, for purposes of design, as the maximum permissible spread. If it is now assumed that the spreads of individual parts of the equipment are of the same form, then the average spread which may be contributed at each of the eleven stages quoted for two coaxial systems in tandem will be 0·27 db.—a very severe limit for commercially produced equipment and one which might prove uneconomic. The application and maintenance of such a limit in a repeatered coaxial (or 12- or 24-channel) line would almost certainly prove impracticable. When the need for extending groups over more than two coaxial links is considered—the need for five such links in tandem is already foreseen—the difficulties are proportionately increased. Fortunately, the position is not quite so serious as would appear from the foregoing over-simplified picture.

"Slopes" and "Rolls."

The spreads introduced by the various component parts of the system may be placed in three categories:

(1) "Slopes"
(2) "Rolls"
(3) Combinations of (1) and (2)

simple examples of which are shown in Fig. 3.

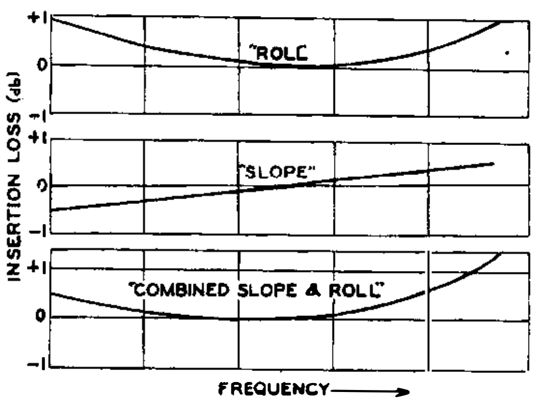


FIG. 3.—ADDITION OF "SLOPE" AND "ROLL."

The "slope" of an insertion loss-frequency characteristic will be taken for the purpose of this article as being proportional to the difference between the insertion losses at the extremities of the frequency band in question. The term "roll" is one commonly used but without, it is believed, any attempt at strict definition. It will here be taken as referring to a characteristic which has one or more turning points and equal losses at the extreme frequencies of the band. The numerous band-pass filters in the translating equipment, taken by themselves, will normally have rolls with an odd number of turning points in the band for which they are designed. Over a more restricted range, such as the 48 kc/s group range in the supergroup filters, they will have an indefinite number of turning points or, in some cases, contribute mainly slope to the overall spread.

Typical Characteristics: Translating Equipment.

Typical insertion loss characteristics of group translating equipments are shown in Fig. **4**. Group 5

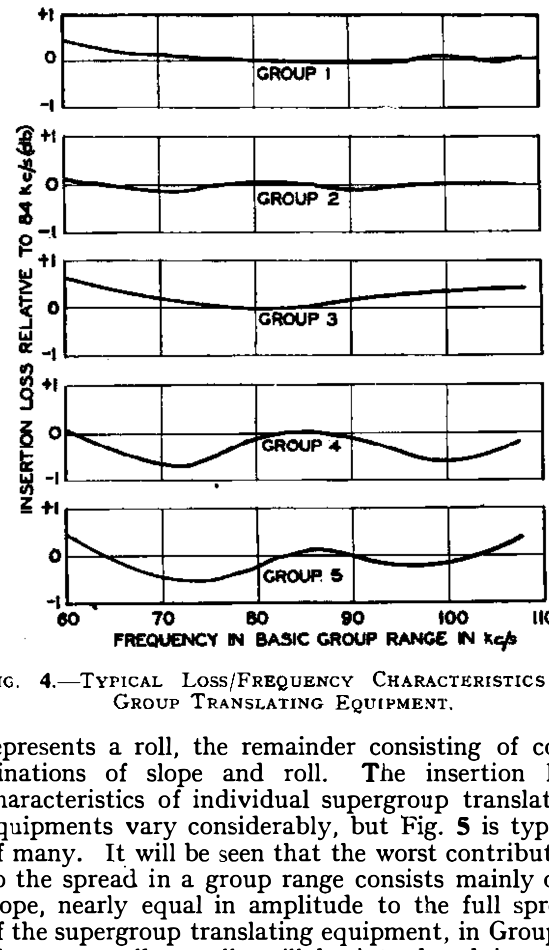


FIG. **4**.—TYPICAL LOSS/FREQUENCY CHARACTERISTICS OF GROUP TRANSLATING EQUIPMENT.

represents a roll, the remainder consisting of combinations of slope and roll. The insertion loss characteristics of individual supergroup translating equipments vary considerably, but Fig. **5** is typical of many. It will be seen that the worst contribution to the spread in a group range consists mainly of a slope, nearly equal in amplitude to the full spread of the supergroup translating equipment, in Group 1. Slopes as well as rolls will be introduced in other group ranges, the rolls being predominant in Groups 4 and 5. The amplitude of the spreads resulting from adding the characteristics will clearly depend upon whether slopes or rolls are added and upon their signs. Slopes will obviously add algebraically. This can also apply to rolls with the same number of turning points, but when slope is added to roll the resulting spread will always be less than the sum of the component spreads. A simple example ꞩ shown in Fig. 3, where a spread of 1 db. in the orm of a slope is added to a spread of 1 db. in the orm of a roll having a single turning point to pro-

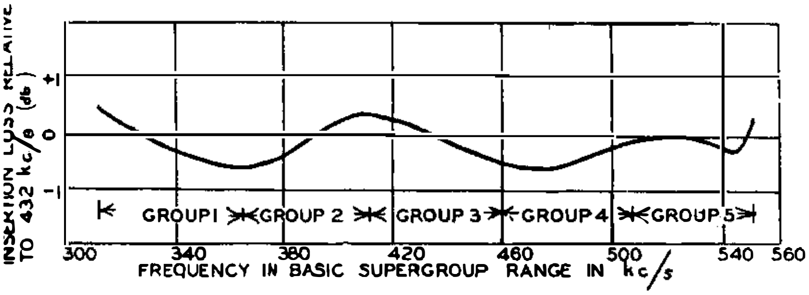


FIG. 5.—TYPICAL LOSS/FREQUENCY CHARACTERISTICS OF SUPERGROUP TRANSLATING EQUIPMENT.

luce a combined spread slightly in excess of 1·5 db.

In the examples given in Figs. 4 and 5 it will be ꞩeen that the characteristic of the group translating ꞩquipment for Group 1 consists mainly of a negative ꞩlope of 0·4 db. and the supergroup translating ꞩquipment mainly of a negative slope of 1·1 db. in he Group 1 range. Due to the fact that lower ꞩidebands are selected in the translating process, ıowever, the upper and lower frequencies in the ꞩroup range are reversed in the basic supergroup ꞩpectrum and the difference of the two slopes must ꞩe taken. The net result is that the overall spread n the Group 1 range of the two equipments taken ꞩogether is about 0·7 db., i.e. better than that of the ꞩupergroup translating equipment taken alone. In he more complicated case of Group 4 a spread of)·8 db. in the group translating equipment combines vith a spread of 0·5 db. in the supergroup translating ꞩquipment to give an overall group spread of 1·1 db.

Through Group Filters.

Typical characteristics of a number of production hrough-group filters are shown in Fig. 6. It will

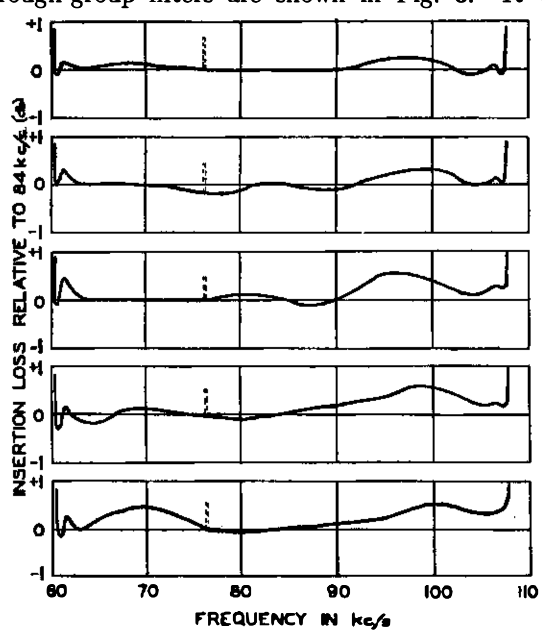


FIG. 6.—TYPICAL LOSS/FREQUENCY CHARACTERISTICS OF THROUGH-GROUP FILTERS.

be seen that there are points of marked similarity between them, a fact which will tend to make the spreads of a number of filters connected in tandem add arithmetically, as emphasised in Part 1 of this article. As was also mentioned in Part 1, the filters are specifically designed to have an appreciable attenuation at a frequency of 60 kc/s for the purpose of suppressing 60 kc/s pilot tones incoming on 12-channel lines so that the spread of a through-group filter is measured over a slightly restricted range, 60·6–107·7 kc/s, corresponding to the limiting sideband frequencies required to be effectively transmitted. Two very sharp peaks of attenuation are seen to occur in the passband. These are due to secondary crystal resonances and are unavoidable in this type of crystal filter. By careful design and manufacture they are made to appear at frequencies very close to 76 kc/s, where they are between channel bands and do not contribute to the effective spread.

The Characteristics of Coaxial and 12-channel Lines.

It might perhaps be expected that the spread over a group range of frequencies introduced by the coaxial line would be in the form of slopes only and that these would be of small amplitude except in the lower supergroups. The characteristic in Fig. 7

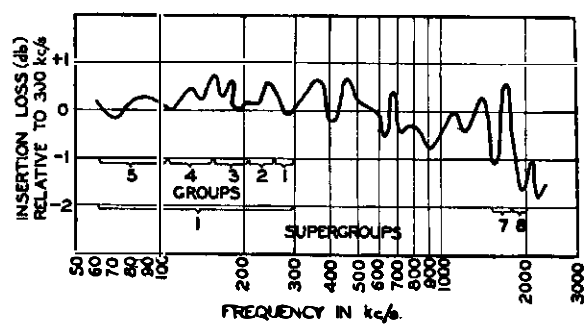


FIG. 7.—TYPICAL LOSS/FREQUENCY CHARACTERISTIC OF COAXIAL LINE.

shows that neither is necessarily true. Rolls of appreciable amplitude occur in each group range of Supergroup 1 and, as in the supergroup translating equipment, these may have an even number of turning points. In the combined range of Groups 4 and 3 of Supergroup 7 (1,604–1,700 kc/s) the spread due to the line is 1·6 db.

The characteristic in Fig. 8 is that of a group

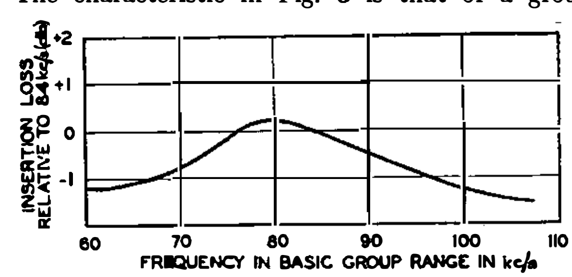


FIG. 8.—TYPICAL LOSS/FREQUENCY CHARACTERISTICS. HIGH FREQUENCY LINE-UP, G.D.F.—G.D.F.

extended over a 12-channel line about 100 miles in length. It represents overall insertion loss between the G.D.F.s and therefore includes two sets of group modulating equipment. The latter perform the function, parallel to that of the group translating equipment, of translating frequencies in the basic group range (60–108 kc/s) to the 12-channel line range (12–60 kc/s) and vice versa. Unlike group translating equipment, however, they incorporate only low-pass instead of bandpass filters. In conjunction with the absence of any need for combining the outputs of a number of filters, as occurs in the group translating equipment, this fact allows the group spreads introduced by the group modulating equipment to be negligible in comparison with that of the 12-channel line.

Overall Characteristics.

The manner in which the spreads of component parts of a system will add is clearly very complicated. It is, in fact, impossible to assess the total spread from the component spreads without some further information. Given the frequency characteristics of individual parts it is a simple matter to determine the overall characteristic and total spread. Given only spreads it is impossible to arrive at any conclusion other than that the total spread will not exceed the arithmetic sum of the component spreads. On the other hand, the assumption that the spreads will add arithmetically is unsatisfactory from a design standpoint. A new method of specifying a frequency characteristic in such a way that when combined with others, specified in the same way, the overall characteristic can be determined with a fair degree of accuracy seems to be required. So far as is known, no such method exists at present, but a solution is being sought.

Only a limited experience has so far been obtained in applying through-group working to coaxial systems with standard equipment. Two such systems have been linked satisfactorily. Measured spreads on the through-groups ranged between 3 and 5 db., spreads of more than 3 db. being tolerable when the circuit requirements do not call for the channel equipment to operate under maximum or minimum

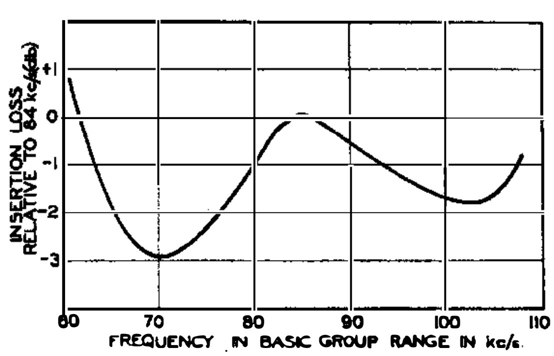


FIG. 9.—TYPICAL LOSS/FREQUENCY CHARACTERISTIC OF OVERALL CIRCUIT—2 COAXIAL SYSTEMS AND A T.G.F.

output conditions. Fig. 9 shows one of the overall group characteristics actually obtained.

Further Developments.

Although there is some evidence to suggest th the linking of two coaxial systems by direct throug group connection will generally be satisfactory it h become necessary to consider what steps must taken to ensure acceptable overall group sprea when as many as five such systems are linked tandem. There are several possible courses. O suggestion which has been put forward may described as the "selected jointing" of grou Under this scheme the characteristics of all t groups on two adjacent systems to be connected tandem would be obtained and compared. I examination, a pair of groups having complementa or least similar, characteristics would be selected, o on each system and jumpered together, via throug group filters, at the G.D.F. The overall gro characteristics and those of the third system wo then be measured and the process repeated. Althou such a scheme has the merit of electrical simplici and would frequently effect an improvement, it co not be relied upon always to give satisfactory sprea and has serious disadvantages from a utilisati aspect on the score of flexibility. The scheme wo only be satisfactory when applied to a perman network and would break down when the need re-routing a group arose.

Other solutions include (*a*) the equalisation individual parts of the translating equipme (*b*) overall group equalisation, and (*c*) facilities equalising at each G.D.F. in the network. Only t latter is a complete solution to the problem, si the first does not cover the through-group filter a line spreads, and the second might allow differen in sideband level which were too great for satisfact signal-to-noise and signal-to-crosstalk ratios on cert channels. The determination of the requirements such an equaliser is not simple. Strictly, it sho cover the condition in which every part of the syst has the maximum possible spread of every possi form. In practice, it will probably be designed analysis of the measured characteristics of work groups, including those on 12- and 24-channel lin

It is perhaps true to say that whereas the devel ment of the through-group filter made through-gr working possible, only the development of flexible group equaliser will make their repeated in a single transmission path a practicable propositi

INSTALLATION DETAILS

The preceding sections of this article have descri the electrical design and performance of the co ponents required to effect through-group worki The following section describes the physical form the equipment concerned, with particular reference the through-group filter bay, the group distribut frame and the cabling between these units and normally installed components of carrier and coa terminal equipment.

Through-Group Filter Bays.

In practice each through-group filter of contract manufacture comprises a series of six filter u wired in tandem and mounted on a standard 19 panel. The general appearance of a typical panel is shown in Fig. **10**. The four large copper cans seen in the centre of the panel contain the crystal filters and are hermetically sealed to give protection from

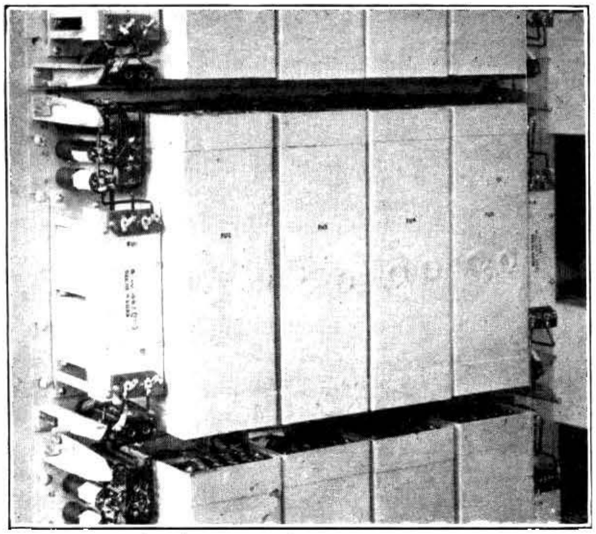


Fig. **10**.—Through-Group Filter Panel.

changes in humidity as well as from electrical and physical disturbance. The two smaller units to either side of the crystal filters contain coil and condenser filter units, which ensure that the high discrimination given by the bandpass crystal filters is maintained well beyond the edges of the band. The other smaller units on the panel are impedance matching transformers and attenuators, which give each filter an insertion loss of 29 db.

A standard 10 ft. 6 in. repeater equipment bay accommodates 20 such panels, 10 on each side, and the bay, when fully equipped, provides filters for ten through groups, two filters being required for each group, one in each transmission path—go and return. Segregation of the filters into " go " and " return " groups is not necessary, the filters being taken up in sequence as required.

Cabling.

In common with the cabling arrangements for all H.F. equipment dealing with frequencies in the 60 kc/s to 108 kc/s range, the cabling of the transmission channels to and from through-group filters is made with single coaxial type cable throughout. This cable is essentially a stranded centre conductor surrounded by a braided copper screen and insulated from it by layers of cotopa, or low loss insulating material. The copper screen is lapped with tape and braided overall to form a flexible coaxial type cable. This type of cable is also used for jumper cross-connections on the G.D.F., and when used with the special terminal strips on the filter bays and on the G.D.F., provides an effective and continuous electrical screen for the centre coaxial conductor.

On the through-group filter bay the input and output connections are arranged to the left and right hand respectively, of the panel immediately behind the level test sockets. From these positions the circuits are cabled in separate " in " and " out " groups to screened terminals at the top of the bay ; the ten input circuits occupying the first ten terminals and the output circuits the second set of ten. Fig. **11** shows a terminal panel from which it can be noted that the screens of both the incoming and outgoing

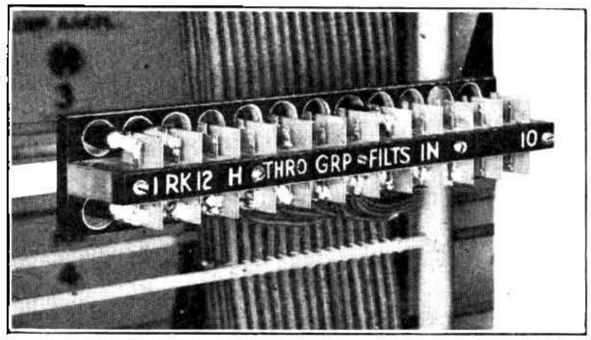


Fig. **11**.—Connection Strip used on G.D.F.

cables are sweated to the copper baseplate through which the cables pass and over which the copper screening can is fixed. The centre conductors are jointed together as shown.

From here the cabling is made direct to the connection strips on the front and rear of the G.D.F. for the output and input circuits respectively from the filter bay.

Group Distribution Frame.

The G.D.F. is designed in extensible units, each occupying the space of two standard equipment bays, 10 ft. 6 in. high. It provides a vertical jumper field between connection strips which are horizontally mounted and arranged in columns of 20 in the left-hand bay on the front of the frame and on the rear of the right-hand bay.

Although the right-hand bay was originally intended to be unequipped, it is likely that limited use will be made of it to accommodate the special type connection strip shown in Fig. **12**. These strips

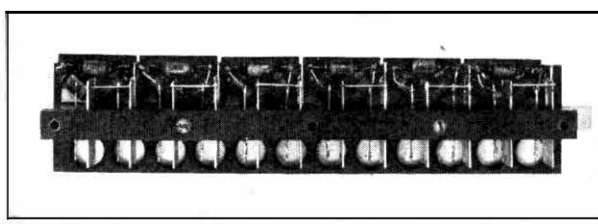


Fig. **12**.—G.D.F. Connection Strip with 29 db. Pads (cover removed).

incorporate between each pair of terminals a simple attenuator network giving a loss of 29 db. This 29 db. attenuator is used mainly in connection with 24-circuit working to give the necessary level correction at the G.D.F., but could be inserted to simulate the filter loss where one is not included in a through group connection.

The jumper field is constructed of vertical and horizontal tubular members arranged in ladder fashion behind the connection strips. This framework provides anchorage for the cabling and with the diagonal arrangement of connection strips mentioned above, ensures the jumper connections being run clear of the incoming and outgoing cables. The general construction of the frame can be seen in Fig. 13, which clearly shows the spacing of the main

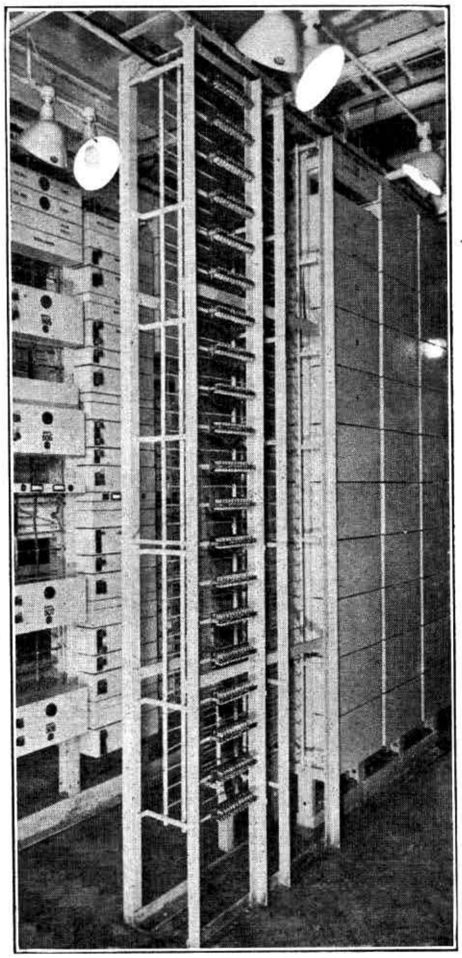


FIG. 13.—G.D.F. AND THROUGH-GROUP FILTER BAYS.

end uprights to enable jumpers to be passed from one unit to another where the frame comprises more than one unit installed *en suite*.

The frame provides a flexibility point for the interconnection of all H.F. equipment handling frequencies in the range 60 kc/s to 108 kc/s.

Circuits carrying signals incoming to the frame terminate on the front and those carrying signals outgoing from the frame, on the rear.

As there is a difference of 29 db. between circuits at the G.D.F. liability to crosstalk is minimised by arranging the high level (— 8 db.) and low lev (— 37 db.) circuits in separately cabled groups and b disposing the corresponding connection strips sym metrically about the horizontal centre line of the fram with the high level circuits on the upper portion.

A typical connection strip terminating throug group filters is shown in Fig. 14, from which th

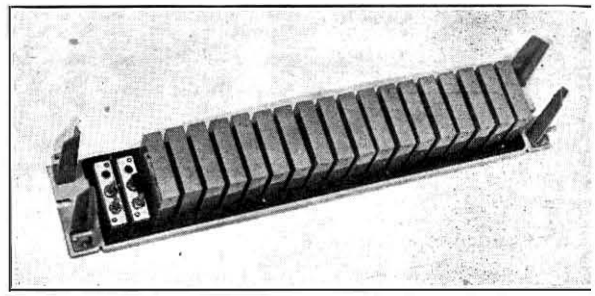


FIG. 14.—SCREENED TERMINALS ON THROUGH-GROUP FILTE BAY.

screening arrangements can be seen. The metall screens of both the cables and jumpers are terminate on the rear edge of the vertical copper screenir plate which passes right through the strip.

It is on this frame that the interconnection through-group filters with group translating an carrier group modulators is made. The line diagran in Figs. 1 and 2 show the insertion of through-grou filters in coaxial routes in tandem and in the lir between coaxial and a 12-channel lines.

Station Layout.

In the design of repeater station layouts, the G.D.I is located as near as practicable to the geographic centre of the H.F. equipment, mainly to avo long cable lengths. Since both the G.D.F. ar through-group filters are not current-consuming iten it is often convenient, although, of course, not essenti to arrange both in the same suite. Provision however, made on the filter bays for standard busb assemblies to permit of their being installed if ne be, in a suite of current consuming equipment so th power feeds can be made continuous.

Installation of current consuming bays immediate adjacent to the G.D.F. is avoided wherever possib as the special construction of the frame rende difficult the connection of power leads to the en of the busbars on the bay.

Acknowledgements.

The authors wish to acknowledge with thanks t assistance given by the General Electric Co. a Standard Telephones and Cables Ltd. in the provisi of photographs.

A New Tool for Driving Steel Tubes into the Ground

IN connection with some recent experimental work it was necessary to find a quick and reliable method of driving 3 ft. 6 in. thin steel foundation tubes into most types of soil to a depth of 2 ft. 6 in. It was essential that the fitting of the tube should not suffer distortion in the driving process so that the superstructure should not be delayed or made difficult.

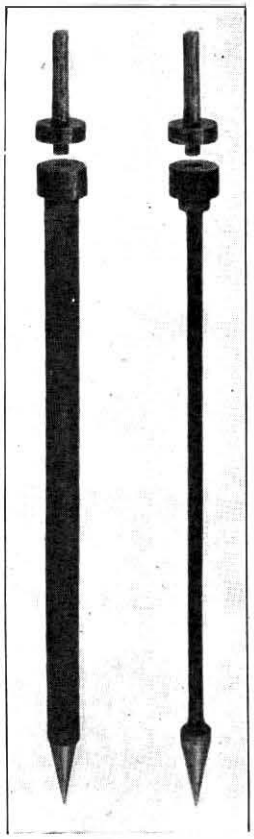


FIG. 1

The tubes used in the experiment were of hardened and tempered chrome-molybdenum steel and were 2¼ in. external diameter, with a wall thickness of 16 S.W.G. (0·064 in.) manufactured to close tolerances. It was desired that the tubes should be driven by a self-contained mechanical aid (such as the portable petrol-driven road breakers which have been used by the Post Office Engineering Department for some years) which could also be used in its normal capacity, and a special tool for use in this type of machine has been developed in the Engineer-in-Chief's Office.

The tool, which is illustrated in Fig. 1 is in two parts. The larger portion temporarily provides the tube with a spiked end and a driving head (see illustration with tube in place). The spike fits the inside of the lower end of the tube to close limits, whilst the driving head is shaped and grooved to fit both the inside and the outside of the upper end of the tube to similar limits. The smaller portion constitutes a driving hammer with a hexagonal shank to fit the particular type of road-breaking machine to be used (that is, it is similar to the shank of the normal road-breaking picks) and a spigot to locate the hammer centrally in the driving head. This spigot is necessary for safety reasons to prevent the road breaker vibrating off the driving head during the driving operation. It was considered necessary to make the tool in two parts to ease the work of the operator in setting up the assembly in position for driving (Fig. 2). Tommy bar holes are provided in the driving head to facilitate removal of the tool from the tube after driving is completed.

An experimental tool was made by Pegson Limited, of Coalville, Leicestershire, for use with their own type of road breaker and proved very successful. Typical times taken to drive a tube to a depth of 2 ft. 6 in. in soft ground and hard were 30 seconds and 2 minutes respectively. No distortion of the upper end of tube was apparent and the tool was readily removed on completion of the driving operation. What little soil gets into the tube during driving falls into the recess made by the spike or is withdrawn with the tool. The tube is therefore left empty to the required depth. There should be no difficulty in driving tubes of larger diameter by this method.

Consideration is being given to driving Spikes, Earth, No. 2 by similar means. E. W. A.

FIG. 2

Decay in Poles

P. R. GERRY, A.M.I.E.E.

U.D.C. 621.315.668.1

This article describes the causes and effects of decay in wood poles and the methods employed for its detection.

Introduction.

WOOD poles have been the principal form of support used for overhead telephone and telegraph lines in this country since such lines were first installed. They have always been superior to other types in initial cost, upkeep and ease of attaching the many varied fittings required. Compared with available alternatives their weight is much less, which is of considerable importance as regards transport and handling, including erection.

Most of the 4,000,000 poles in use on Post Office lines in this country are of Scots Pine (*Pinus Sylvestris*) imported from Scandinavia and Russia. Other species (e.g. Larch, Douglas Fir, etc.), both imported and home grown, are in use but in comparatively small quantities, and none has been in use long enough to enable any useful life comparison to be made with Scots pine. It is not unusual for well-creosoted Scots pine poles to have a life of 50 years or more; in fact, there are many poles in sound condition still in use which were erected over 70 years ago. There are many poles, however, whose useful life is shortened considerably, due to traffic accidents, insect attack or fungal growth.

There is not much that can be done to lessen the risk of damage by collision, apart from placing poles as far as possible from the roadway. The risk of insect attack is remote. The insect most likely to attack poles in this country is the grub of the Longhorn beetle. These grubs attack green timber only, whereas poles are seasoned before issue. If by chance any insect were in the timber at the end of the seasoning period it would most likely be destroyed by the subsequent creosoting process. Other types of insect likely to attack timber in this country show a marked preference for hardwoods, whereas poles, generally, are of the softwood class. Although the prospect of insect attack is remote, isolated cases have occurred and the possibility of this form of attack should not be ignored entirely. The signs indicative of insect attack are bore holes varying in size, tunnels in the wood generally in the direction of the grain, and sometimes the presence of finely powdered wood in the form of bore-dust. The chief cause of a short life is fungal growth. Signs of the growth, as with those of insect attack, may not be obvious and there is therefore some risk, with either form of attack, of a pole collapsing without warning. As such an event may have serious consequences to staff working on or near the pole, to passers-by or to nearby property it is important that the presence of the insect attack or fungal growth should be detected and adequate precautions taken before collapse occurs.

General appearance and age do not in themselves provide reliable guides as to whether or not a pole is sound and it is necessary to apply practical tests to ascertain the condition of the pole. The practical tests will reveal the presence of both insect and fungal attack, but before describing them a few details of the cause and effect of decay will be of interest and assist in demonstrating the value of the tests.

Cause of decay.

Fungal growth on timber in the vicinity may be responsible for the decay of a pole. The growth may be in the form of a "cap" (toadstool), a "bracket," or a "flat skin." A single fruit body, e.g. a single toadstool, can produce millions of spores which when liberated may blow about and settle on any timber in their path. The spores can find the food they require in the wood and given moist and warm conditions and a supply of oxygen they can develop at a rapid rate and cause the timber to decay. The seat of decay in a pole is often inside and sometimes below ground, due to cracks, etc., providing a path for the spores and for the oxygen required for the spores' development.

For the development of fungal growth a moisture content greater than 20 per cent. of the dry weight of the timber is necessary. It is possible, of course, to reduce the moisture below 20 per cent. by seasoning, but subsequent exposure to the elements would prevent the low moisture content being maintained. For this reason a preservative, usually creosote, is injected into the pole. The creosote is applied when the seasoning process has reduced the moisture content to 25 per cent., as at this value the creosote, when applied under pressure, will impregnate the whole of the sapwood of most of the softwood species. The heartwood is generally resistant to decay, but the sapwood is very susceptible to attack and it is important therefore that the whole of the sapwood should be thoroughly impregnated. In addition to preserving the pole against future attack by fungus, the creosoting process will destroy any fungus spores or fungal growth which may be present.

The poles are seasoned by being stacked, preferably under cover, in open formation which enables air to circulate freely around all poles. Before being seasoned the moisture may exceed 100 per cent. of the dry weight of the wood and it is often several months, dependent on the weather, before sufficient moisture has evaporated from the wood cells to enable the creosote to penetrate to the required depth. This method of seasoning, although slow, enables the moisture to evaporate gradually and thus avoids the splitting which occurs when the outside of the pole is allowed to become much drier than the inside.

The moisture content is found by weighing small samples of the pole and then placing them in an oven. The samples are weighed at intervals until no reduction in weight occurs. The difference between the initial and final weights expressed as a percentage of the final weight indicates the moisture content. The samples may be taken from various parts of the pole and although the same moisture content value may be found in several samples from the same pole it is possible that an isolated pocket of sapwood contains too much moisture to enable perfect creosote impregnation to be effected. Imperfect creosote impregnation may also occur during the actual creosoting process. The poles are creosoted in parcels—the size of which depends on the capacity of the creosoting cylinder—and although the total quantity of creosote absorbed by the poles can be controlled, the resistance to penetration of individual poles may vary and it is found in practice that part of the sapwood sometimes escapes thorough impregnation. The inadequately creosoted wood may be the seat of subsequent fungal attack as the spores from the fungal fruit-body may be able to reach it through a crack in the outer surface of the pole or perhaps through a hole bored into the pole after creosoting. Owing to the large number of poles which may have to be treated in any one year (up to 300,000 may be required for Post Office use alone) it will be evident that it is not practicable to guarantee that every pole will be capable of resisting fungal attack.

The effect of insufficient seasoning is illustrated by returns which have been made on decayed poles detected during a two-year period. Altogether 4,210 decayed poles were found, and 2,754 of them were creosoted during the years 1914–1926, when the demand for poles exceeded the supply to such an extent that it was found necessary to shorten materially the normal seasoning period. The remaining 1,457 decayed poles were creosoted between 1880 and 1913 and from 1927 onwards.

Effect of Decay.

The effect of decayed wood on the strength of a pole will, of course, depend on its extent and position. Fig. 1 shows the cross-section of a pole where the decay consists of a complete ring inside the pole—between the heartwood and sapwood. From the strength aspect such a pole is the equivalent of a tube, only the outer layer of sound sapwood resisting bending stress. Assuming a light pole 28 ft. long is set 5 ft. in the ground and the layer of sound sapwood is 1¼ in. thick, it would be capable, theoretically, of resisting a bending load of 865 lb. applied 2 ft. from the top in a horizontal direction. A similar sound pole would break with a bending load of 1,000 lb. When the layer of sound sapwood is reduced to 1 in. the failing load would be 770 lb. It will be seen, therefore, that internal decay would need to be very extensive before there was any appreciable risk of the pole breaking.

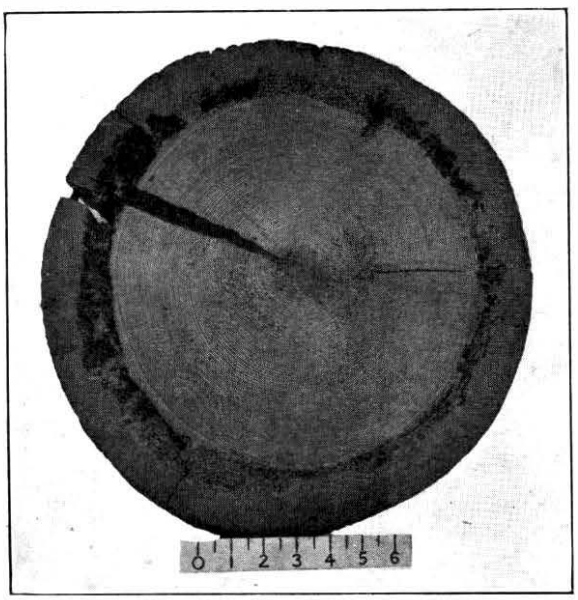


FIG 1.—INTERNAL DECAY.

The most dangerous position for decay is on the outside of the pole near the ground line. It is at this point that the maximum bending stress occurs and it is here that conditions are most favourable for fungal growth. Of the 4,210 decayed poles already referred to, 3,483 were found decayed at the ground line. The presence of even a small area of decay at this point may result in a serious reduction in the strength of the pole. Considering the case of the surface decay shown in Fig. 2, if it existed in a 28-ft. light pole and the depth of decay was 1 in., the strength would be reduced from 1,000 lb. to 654 lb.; for a 1½-in. depth of decay to 506 lb., and when the depth was 2 in. to 380 lb. When the width of the decay extends for more than half the circumference of the pole the strength values for the depths quoted would be 380 lb., 194 lb., and 83 lb. respectively. The strength values quoted are based upon the assumption

FIG 2.—SURFACE DECAY.

that the decay is at or near the ground line. When the surface decay is near the top of the pole, as is sometimes found at arm slots, it would need to be extensive to involve risk of breakage.

In calculating the safe working loads for poles a minimum factor of safety of 3·5 is allowed, and this provides a generous margin for decay and other defects. It is evident therefore that a pole must be decayed to a considerable extent before it will fracture as a result of, say, a man ascending or working at the top. The bending moment on a pole while a man is climbing steadily or working in a fairly stationary position is not likely to exceed 200 ft.-lb., and the resistance moment of a 28-ft. light pole with a 2-in. depth of decay extending over more than half the circumference of the pole at the ground line would not be less than 1,740 ft.-lb. On a pole carrying an unbalanced load, e.g. an inadequately stayed angle, terminal or distribution pole, the risk of collapse due to a man climbing or working at the top would be increased. Similarly severe stresses would arise if the pole were caused to sway unduly.

Detecting Decay.

Two simple tests are used to detect decay, the hammer test and the prodding test. The former consists of striking the pole a sharp blow with a hammer and is intended primarily for ascertaining the internal condition of the pole. If the timber is sound the blow will produce a characteristic ring whereas extensive internal decay will be denoted by a decidedly hollow note. The hollow note is obtained only if the pole is struck within a few inches of the affected portion, and it is possible therefore by striking at different places to determine the extent of the decay.

In the prodding test the outer surface is prodded with the blade of a knife, screwdriver or similar tool. When the tool is inserted between the fibres of sound wood considerable resistance will be met and the fibres will grip it; with decayed wood, however, no appreciable effort will be required to penetrate the wood and the fibres will exert no grip. The difference between the "feel" of sound and decayed wood is so noticeable that once an officer has applied the test to both he should have no difficulty in deciding whether timber is sound.

The systematic detection of decay is carried out by qualified staff who have received special training including instruction on the causes, effects and prevention of decay and the application of the hammer and prodding tests on actual poles in various stages of decay.

Classifying Decayed Poles.

In addition to being either sound or dangerous, poles can be decayed so slightly that no appreciable reduction in strength results. Small patches of decay often remain inactive for long periods or the decay may develop at a very slow rate. Where the decay is slight the pole is classified as suspect. There are therefore three classes in which the pole being tested can be placed, and the symptoms indicative of each class are shown in Table 1.

TABLE I

Classification	Type of Test	Symptoms
Dangerous (extensive decay)	Hammer	(*a*) decided hollow sound
	Prodding	(*b*) decayed wood of a depth greater than 2 in. irrespective of the area affected (*c*) decayed wood of a depth greater than 1 in. extending beyond one-third of the circumference of pole
Suspect (slight decay)	Hammer	(*d*) dead or dull sound (*e*) slight penetration of hammer head through outer surface
	Prodding	(*f*) decayed wood of a smaller extent than (*b*) and (*c*)
Sound (no decay)	Hammer	(*g*) good ring
	Prodding	(*h*) no decayed wood

It will be noted that poles producing a decided hollow note are classified as dangerous, although the internal decay responsible for the hollow note needs to be extensive before this classification is warranted. This is due to the impracticability of ascertaining the depth and uniformity of the outer layer of sound sapwood. The depth could, of course, be checked by taking borings from the pole, but it would not be practicable to take sufficient to enable a reasonable assessment of the depth of sound sapwood existing throughout the pole.

Testing Routine.

To ensure that poles are tested thoroughly and in a methodical manner with due regard to safety and economy of time the tests should include the following operations, which should be done in the sequence shown. When any one operation indicates that the pole is in a dangerous condition the remaining operations need not be done—

(*a*) Apply the hammer test at and near the ground line in several places all round the pole and also to the parts of the pole within reach from the ground.

(*b*) Apply the prodding test to the same parts of the pole as in (*a*).

(*c*) Excavate the ground to expose 1 ft. of the pole below ground line. Apply the hammer test to the exposed part.

(*d*) Apply the prodding test to the exposed part.

(*e*) Replace and consolidate the earth.

(*f*) Apply the hammer test all round the pole at approximately 12-in. intervals, commencing from the point within reach of the ground and working towards the top.

(*g*) Apply the prodding test to all points where the hammer test indicates that the pole is suspect.

The detection of internal decay by taking borings by a special hollow augur has been abandoned. The boring obtained by the tool indicates the condition of the timber in the immediate vicinity only. To ascertain the extent of the decay it is necessary to take several borings and as each boring weakens the pole there is a considerable risk of even sound poles being rendered dangerous.

Treatment of Decayed Poles.

Poles judged to be dangerous are marked immediately they have been tested with a large-headed nail coloured red with a letter "D" embossed on it. Such poles should be changed as early as possible. If it is necessary to work on the pole before the replacement can be effected it should be strengthened by two stout ladders placed on opposite sides and securely lashed together and to the pole itself. The top of each ladder should be suitably stayed in opposite directions to prevent lateral movement of the two ladders.

Poles in the suspect class are marked with a large-headed nail coloured red with an embossed letter "S." Such poles may be climbed but are scheduled and re-inspected at intervals to ascertain if and when they become dangerous.

When a pole is suspect due to slight surface decay the decayed wood is removed and the exposed sound wood given a liberal dressing of a creosote and tar mixture.

In addition to the systematic testing by qualified staff, the hammer and prodding tests must continue to be applied to all poles at the ground line and at any other point where decay is suspected before any pole is ascended. Although this general test is not so thorough as the main test it is sufficient to detect decay which has reached a dangerous stage.

Decay has sometimes started from a point where the creosoted layer of sapwood has been broken by cutting arm slots or by boring bolt holes. The exposure of the uncreosoted wood during cold weather involves little risk of the timber becoming infected, but during warm weather there is a danger of spores alighting on the wood and finding conditions suitable for germination and development. The application of creosote by a brush is sufficient to destroy any spores that may exist or may alight on the wood if done promptly and thoroughly.

It is evident that the decay of poles is inevitable, but it is clear that the presence of decay can be detected by simple means. If the tests described are applied at sufficiently frequent intervals and the appropriate action taken, the risk of accident due to decayed poles collapsing should be eliminated.

Book Review

"Telegraph Transmission Theory." E. H. Jolley, M.I.E.E. 124 pp. 53 ill. Sir Isaac Pitman & Sons, Ltd. 7s. 6d.

The author of this book states in his preface that the material was prepared for inclusion in a comprehensive text book on telegraphy, but he hopes that the advance publication of this particular section will fill a long-felt gap in telegraph literature. It can be said at once that his hopes are certain to be realised. The theoretical work of Lord Kelvin and W. W. Malcolm in telegraph transmission has been available to engineers for very many years but little practical use has been made of it, and little use could be made of it until the principles and definitions of telegraph distortion and margin were formulated some 20 years ago. Immediately, the application of telegraph transmission theory became a subject of the greatest practical importance, and throughout the intervening period engineers and students of telegraphy have been looking for a book such as this, written primarily for the student and of interest to all telegraph engineers.

That the work is part of a larger text book is fairly evident, as the matter has been compressed rather more than would otherwise be desirable. One or two important aspects have been omitted. For example, although the functions and properties of distortion correcting networks are examined, no information is given on curbing or the vibrating (Gulstad) relay, which are also methods of correcting distortion. Similarly, space might have been given to the theory of duplex circuits and the design of duplex balances. These are not used to any extent in the P.O. system, but are of considerable importance to telegraph engineers generally.

Probably conscious of the shortage of space, the author has wasted none on unessentials. Thus on p. 1 the reader is introduced to the concept of the "time-interval" in telegraph signalling; on p. 2 to "characteristic instants of modulation," etc.; and in the first 8 pages to all the ideas, terms and definitions relating to telegraph transmission distortion, and margin. The student would do well to spend a little more time on this section than the space allotted to it might suggest. After that, progress is logical and more leisurely. Sections on D.C. and A.C. transmission follow, and then a useful section correlating steady-state and transient methods. Electric wave filters—an essential part of multichannel systems—are dealt with adequately, as also are the transmission of A.C. signals and the cumulative effects of distortion in tandem-connected telegraph circuits. Diversity working and frequency modulation are described though, as might be expected, somewhat briefly. Most of the mathematics have been removed from the main text into an Appendix. An error has crept into the formula, on p. 77, for the amplitude modulated carrier.

Altogether the telegraph engineer and student will find this book worth serious attention, and their telephone engineering colleagues should not forget that signalling and dialling are in great measure telegraph transmission problems, a clear understanding of which would benefit all engaged in the art of telecommunications.

F. O. M.

The Production and Properties of Silicones

D. W. GLOVER, M.Sc., F.R.I.C
R. L. BULL, B.Sc., F.R.I.C.

U.D.C. 546.287

Certain long chain polymers, rather similar in structure to organic polymers but containing silicon and oxygen atoms instead of carbon atoms, have recently attained commercial importance. These substances are collectively known as silicones and have outstanding electrical, physical and mechanical properties. The authors describe the fundamental methods of the production of silicones and list some of the uses to which they may be put.

Historical.

THE nature of the long organic chains of which elastomers, natural and synthetic fibres, thermoplastic and thermosetting materials are comprised is nowadays widely appreciated, and most engineers are familiar with the properties of the more common of these materials.[1]

It is less well realised that a range of polymers containing the element silicon as a fundamental constituent, and known generically as silicones, has now appeared in the commercial field. An essential difference between these substances and the carbon polymers is that whereas the latter are built by direct carbon to carbon linkages, the silicon atoms of the former are connected by intermediate oxygen atoms.

Bodies of this general type were first examined systematically by Professor Kipping at Nottingham during the early part of the present century, but no industrial development resulted from his work until about 1938, when the first of a series of patents was published by each of two American companies : The Dow Corning Corporation and the American General Electric Company. These described the production of complex silicon compounds which were claimed to be applicable as hydraulic and heat transfer fluids, lubricants and greases with a very low temperature-viscosity coefficient, and as elastomers and insulating varnishes. All these agents are characterised by extremely good electrical properties, water repellency, and extraordinary high temperature resistance, and hence their potential importance in the electrical industry requires no stressing.

The Production of Silicones.

The element silicon does not occur free in nature but, in combination with oxygen as sand or quartz (silica, $Si\,O_2$), and as complex silicates in the form of numerous rocks and minerals, it forms a major proportion of the earth's crust. Elementary silicon is obtained in its crystalline form by heating an intimate mixture of sand and coke in the electric furnace.

$$\underset{\text{Silica}}{Si\,O_2} + \underset{\text{Carbon}}{2\,C} \longrightarrow \underset{\text{Silicon}}{Si} + \underset{\text{Carbon monoxide}}{2\,CO} \quad \ldots\ldots (1)$$

It is also formed on reducing silica with magnesium (the "Thermite" process), considerable heat being evolved by the reaction.

$$Si\,O_2 + \underset{\text{Magnesium}}{2\,Mg} \longrightarrow Si + \underset{\text{Magnesium oxide}}{2\,Mg\,O} \quad \ldots\ldots (2)$$

[1]*P.O.E.E.J.* Vol. 33, p. 127.

The product in this case is a brown amorphous powder, specific gravity 2·35 and melting point about 1500°C.

Owing to certain features of similarity in atomic structure silicon possesses a marked chemical resemblance to carbon, which is exemplified by its ability to form a range of compounds with hydrogen ; for instance

$$\text{silane} \quad \begin{array}{ccc} & H & \\ H & Si & H \\ & H & \end{array} \quad \text{or } Si\,H_4 \text{ is analogous to}$$

$$\text{methane} \quad \begin{array}{ccc} & H & \\ H & C & H \\ & H & \end{array} \quad \text{or } CH_4$$

Any or all of the hydrogen atoms of both these compounds may be replaced by chlorine or other halogen atoms ; thus when carbon disulphide, obtained by passing sulphur vapour through red-hot carbon, is reacted with chlorine in the presence of a catalyst such as manganese or aluminium chloride, carbon tetrachloride $C\,Cl_4$ is produced :

$$\underset{\text{Carbon disulphide}}{CS_2} + \underset{\text{Chlorine}}{3\,Cl_2} \longrightarrow \underset{\text{Carbon tetrachloride}}{C\,Cl_4} + \underset{\text{Sulphur chloride}}{S_2\,Cl_2} \quad \ldots\ldots (3)$$

Also, if an intimate mixture of carbon and silica is heated in a stream of chlorine, the analogous compound silicon tetrachloride is formed :

$$Si\,O_2 + 2C + 2\,Cl_2 \longrightarrow \underset{\text{Silicon tetrachloride}}{Si\,Cl_4} + 2\,CO \quad \ldots\ldots (4)$$

This last substance is the parent body of all the silicones, and their preparation from it may be regarded as taking place in three steps :

STEP 1. *The substitution of organic groupings or radicals for one or more chlorine atoms in silicon tetrachloride.*

Alkyl groups such as

$$\text{Methyl } \left(-\begin{array}{c} H \\ C \\ H \end{array} H \text{ or } CH_3\right)$$

$$\text{and ethyl } \left(-\begin{array}{c} H \\ C \\ H \end{array} - \begin{array}{c} H \\ C \\ H \end{array} H \text{ or } C_2\,H_5\right)$$

are typical radicals which may be made to take the place of chlorine atoms in silicon tetrachloride for the purpose of silicone syntheses, though they are by no means the only ones which can be used. For convenience let any such radical be represented by the symbol —R. Perkin's original method for substituting —R for one or more of the chlorine atoms in silicon tetrachloride necessitates the use of a " Grignard " reagent. Grignard reagents are magnesium compounds of the type

$Mg \genfrac{}{}{0pt}{}{\diagup R}{\diagdown X}$ where X is a halogen atom,

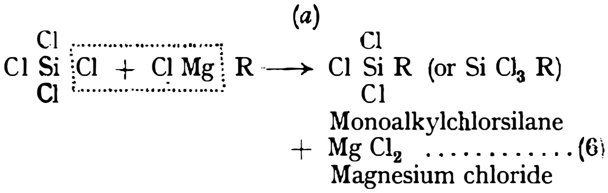
i.e. in the present case chlorine. They are formed by the action of alkyl halides, e.g. methyl chloride (CH_3Cl) on metallic magnesium in the presence of dry ether which acts merely as a catalyst :

$$R\,Cl + Mg \longrightarrow Mg \genfrac{}{}{0pt}{}{\diagup R}{\diagdown Cl} \quad \ldots\ldots\ldots\ldots\ldots\ldots (5)$$

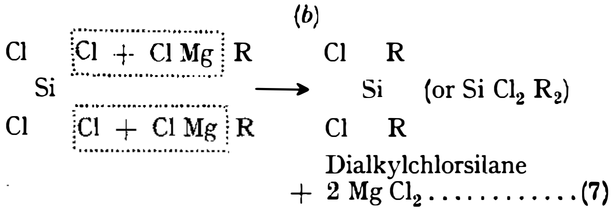
Alkyl chloride   Magnesium alkyl chloride

The magnesium alkyl chloride, which need not be separated from the ether in which it is formed, can react with silicon tetrachloride in the following ways, according to the proportions of the two substances present :

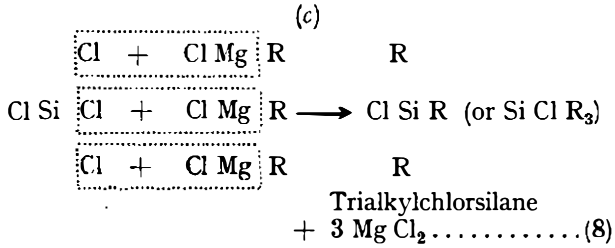
(*a*)



(*b*)



(*c*)



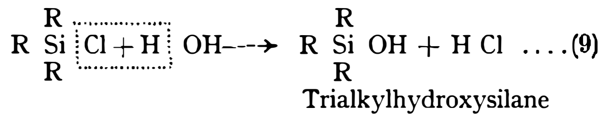
The silicon-containing products are known as mono-, di- and trialkylchlorsilanes respectively, and in the compounds containing more than one alkyl radical it is not necessary for each R to represent the same kind of radical.

There are numerous practical difficulties in operating the Grignard reaction on a large scale, and so long as it remains an essential step in the synthesis of silicones, their price is likely to remain relatively high. Recently, however, it has been found that the alkylchlorsilanes can be prepared directly by passing alkyl chlorides over heated silicon contained in a metallic matrix ; this reaction gives rise to a mixture of products which can only be separated by efficient fractional distillation, and it is not known how far the process has yet been applied commercially.

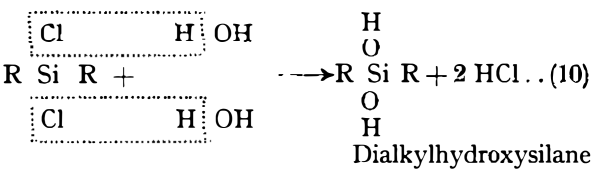
Step 2. *Hydrolysis of the alkylchorsilanes*

Hydrolysis means decomposition by water, and when this treatment is applied to the above products, the remaining chlorine atoms are replaced by the hydroxyl radical (—OH) as follows :

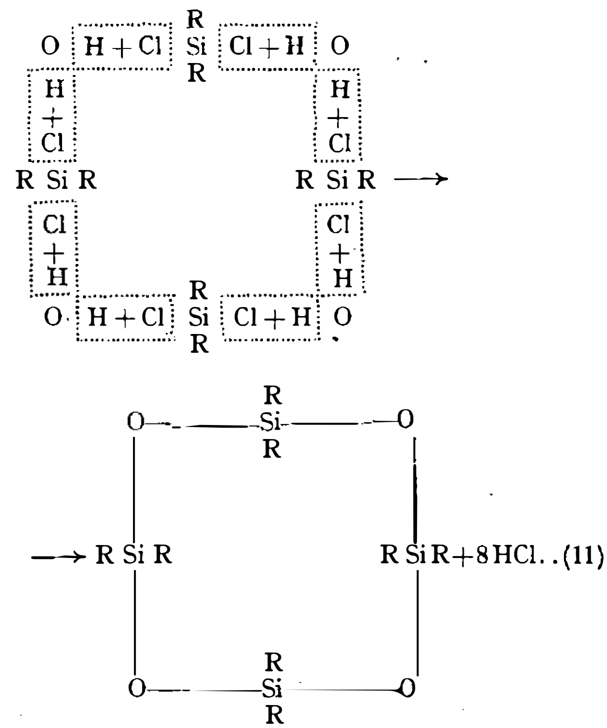
Trialkylchlorsilanes :



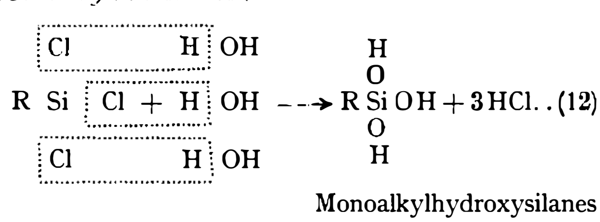
Dialkylchlorsilanes :



In this case simultaneous condensations of three or more dialkylchlorsilane molecules resulting in the formation of varying proportions of cyclic compounds may also occur. Thus, for instance, four molecules of the compound may react to form a " tetramer " as indicated below :



Monoalkylchlorsilanes :



Most of the silicones at present manufactured are derived immediately from the tri-, di-, and monoalkylhydroxysilanes.

Step 3. *Condensation—polymerisation of the alkylhydroxysilanes.*

In the chemical sense condensation signifies the combination of molecules accompanied by the elimination of water. Such reactions often occur spontaneously, or they may be induced in a number of simple ways, and it is shown below how the potentialities of the alkylhydroxysilanes for forming complex structures in this way, increase with the number of hydroxy groups present :

Trialkylhydroxysilane :

$$R_3\,Si\,O\,\boxed{H + HO}\,Si\,R_3 \rightarrow R_3SiOSiR_3 + H_2O \quad (13)$$

The product is a simple compound, known on account of the single oxygen linkage in the middle as an ether. It is clear that no further extension of the chain can occur by condensation.

Dialkylhydroxysilane :

$$HO\overset{R}{\underset{R}{Si}}O\,\boxed{H + HO}\,\overset{R}{\underset{R}{Si}}\,O\,\boxed{H + \ldots\ldots HO}\,\overset{R}{\underset{R}{Si}}\,OH$$

$$\rightarrow HO\overset{R}{\underset{R}{Si}}\,O\,Si\,O \ldots\ldots \overset{R}{\underset{R}{Si}}\,OH + n\,H_2O \quad (14)$$

The action is less restricted in this case, because each additional molecule of dialkylhydroxysilane condensed on to the chain retains a hydroxyl group at its end, so that there is no apparent reason why the reaction should not proceed indefinitely ; this does not happen in fact for reasons which are too academic to discuss here.

Mixture of tri- and dialkylhydroxysilanes :

$$R\overset{R}{\underset{R}{Si}}O\,\boxed{H + HO}\,\overset{R}{\underset{R}{Si}}O\,\boxed{H + HO}\,\overset{R}{\underset{R}{Si}}O\,\boxed{H + \ldots HO}\,\overset{R}{\underset{R}{Si}}R$$

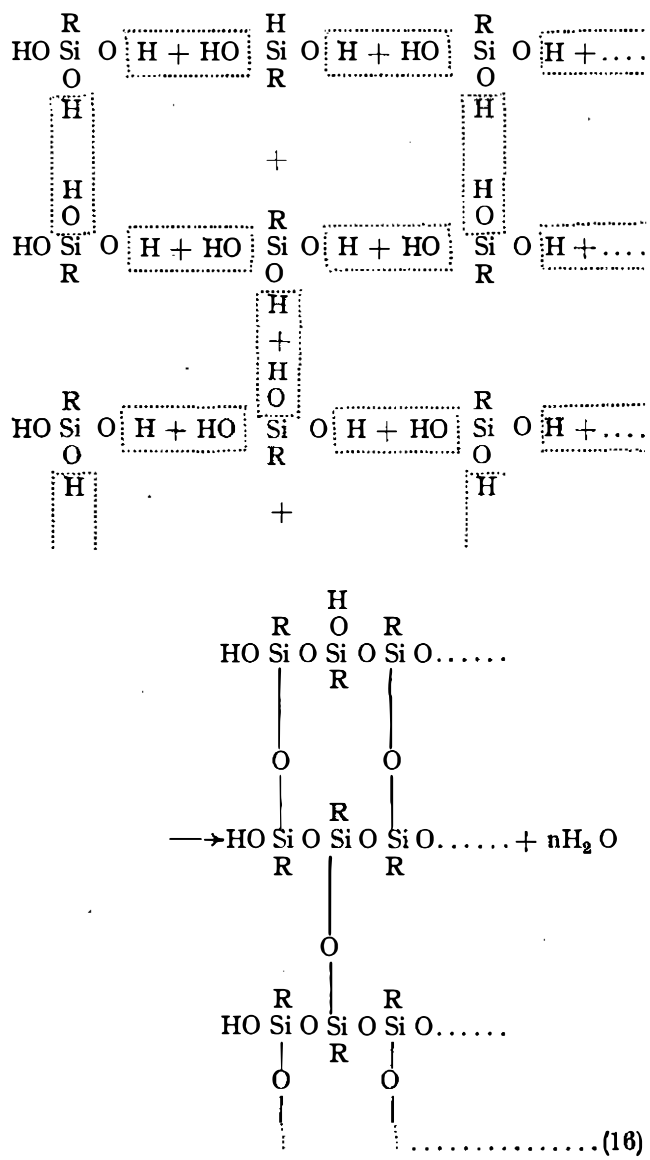
$$\rightarrow R\overset{R}{\underset{R}{Si}}\,O\overset{R}{\underset{R}{Si}}\,O\,\overset{R}{\underset{R}{Si}}O\ldots\ldots\overset{R}{\underset{R}{Si}}R + n\,H_2O \quad (15)$$

This represents a combination of reactions (13) and (14), and it is clear that unlimited extension of the chain is effectively prevented as there are no hydroxyl groups left to react ; the ends of the chain have in fact been " sealed " by the molecules of the trialkylhydroxy compound which have condensed there. With any given ratio of tri- and dialkylhydroxy bodies initially present there is a statistical probability (which can be calculated from the reaction kinetics) that products with a particular restricted range of chain length will predominate.

These can be separated from compounds of extremely different chain length by physical processes such as fractional distillation. It is therefore possible, by the use of a suitable initial mixture, to exercise a considerable measure of control over the reaction, and to obtain a product having fairly sharply defined physical properties.

The particular structure produced by reaction (15) is typical of a silicone oil if the methyl group ($-CH_3$) be used as the radical $-R$, the viscosity of the oil being determined by the mean molecular weight. Suitable choice of other radicals and adjustment of the average chain length enables thermoplastic and rubber-like substances to be obtained.

Monoalkylhydroxysilane :



(16)

It will be seen that, like the condensation products of the dialkylhydroxysilanes, bodies of the above type always possess reactive hydroxyl terminal groups which will apparently enable the condensation to proceed indefinitely, and it is therefore desirable to " end seal " these by the monohydroxy compound as shown earlier. In this case also the proportion of the latter to be used is determined by the desired average molecular weight of the product.

As the four radicals attached to the silicon atom of monoalkylhydroxsilane do not lie in one plane the final product is three-dimensional and hence, by virtue of the rigidity thus conferred, thermosetting.

It must be emphasised that the above description gives only an idealised outline of the main reactions involved in the preparation of silicones. Side processes of the utmost complexity can occur at many stages, giving rise to greater or less quantities of substances which may need ultimately to be separated physically from the desired materials.

Properties of Silicones.

Without cataloguing in detail the various grades of silicones now manufactured, it is possible only to describe their properties in general terms, and for this purpose they may conveniently be classified as follows :

Oils and greases. A range of silicone oils is available for heat transfer, high and low temperature lubrication and vacuum pump lubrication ; the greases are suitable as lubricants and electrical sealing compounds. All these substances are chemically inert, non-corrosive, non-toxic, insoluble in water and water-repellent ; they possess good electrical properties, have a very low vapour pressure, and their viscosities change relatively little with temperature.

As examples of the last two claims, one range of greases on heating at 175° C. for 40 hours loses only about 5 per cent. by weight, whereas the nearest corresponding petroleum greases similarly treated lose 35–60 per cent. by weight. Another grease does not change very much in hardness between —40° C. and 200° C.

The oils burn less vigorously than hydrocarbons, but they possess no rust preventive properties and, as they do not produce oriented layers on metal surfaces, are unsuitable for boundary lubrication.

Their electrical properties are in the following order :

Frequency (c/s)	Permittivity	Power Factor.
10^3	2·85	0·0001
10^6	2·83	0·0002
10^7	2·82	0·0002
10^8	2·81	0·0006

Impregnating varnishes. Several thermosetting varnishes and resins are available which, when used in conjunction with inorganic insulating materials such as glass fibre, mica or asbestos, are claimed to permit the continuous operation of electrical machinery at 175° C. ; they also confer high water resistance upon such equipment.

These varnishes require a curing temperature of 230° C.–260° C., and consequently ordinary solder, melting at about 230° C, cannot be used in apparatus where they are employed ; care is also necessary to avoid annealing associated hard copper and brass working surfaces. They are finding useful applications in the protection of resistors and capacitors for tropical use.

Rubbers. Several grades of silicone rubber, which are stated to be usable between —55° C. and 300° C., are manufactured. These can be fabricated in much the same way as natural and synthetic rubber, and so far appear to have found their main application as heat-resisting gaskets. No quantitative information regarding their elastic properties is yet available.

Probable future developments.

The total amount of silicones of all types which has so far arrived in Great Britain has scarcely risen above experimental quantities ; this is due to import restrictions and to their high price, which ranges from about 15s. to 35s. per lb. Although this will doubtless fall appreciably, it is unlikely that silicones will become sufficiently cheap in the near future for anything but special applications. Many tests have now been made on various grades in this country ; but results have not yet been analysed in detail, though it appears that on the whole they support the American claims. Some small scale manufacturing development has also commenced here, but there is no immediate prospect that this will increase rapidly.

The silicones have already found appreciable application in United States war equipment, and there is no doubt that their field of utility will expand, as they can fulfil requirements which cannot be met by any other known material.

TELEGRAPH AND TELEPHONE STATISTICS—SINGLE WIRE MILEAGES AS AT JUNE, 1947.
THE PROPERTY OF, AND MAINTAINED BY, THE POST OFFICE

REGION	OVERHEAD			UNDERGROUND		
	Trunks and Telegraphs	Junctions	Subscribers*	Trunks and Telegraphs †	Junctions ‡	Subscriber ¶
Northern Ireland	10,188	12,284	35,241	109,780	43,704	145,618
Scottish	19,408	34,264	196,112	801,728	269,217	874,938
Home Counties	12,123	41,466	360,999	1,861,058	468,925	1,469,442
Midland	4,572	34,280	218,829	1,025,803	303,607	1,064,484
North Eastern	8,748	20,817	184,545	872,359	256,092	1,029,442
North Western	1,765	9,153	115,618	670,369	393,652	1,278,519
South Western	6,101	37,671	273,926	974,661	188,532	812,220
Welsh and Border Counties	6,748	31,022	152,217	545,376	87,694	338,954
Provinces	69,653	220,957	1,537,487	6,861,134	2,011,423	7,013,617
London	515	1,005	80,187	917,237	1,844,503	3,835,878
United Kingdom	70,168	221,962	1,617,674	7,778,371	3,855,926	10,849,495

* Includes all spare wires. † All wires (including spares) in M.U. Cables. ‡All wires (including spares) in wholly Junction Cables.
¶ All wires (including spares) in Subscribers' and mixed Junction and Subscribers' Cables.

A 625 kVA Emergency Generating Plant at Leafield Radio Station

L. L HALL

U.D.C. 621.313.1—843 : 621.396.78

A description of the main features of an emergency generating plant at Leafield radio station is followed by details of the acceptance testing of the plant.

Introduction.

PRIOR to the availability of a public power supply at Leafield radio transmitting station, power was generated by duplicate steam turbo-generators. The turbines were supported on the first floor of the power house and discharged low pressure steam into condensers which were located on the ground floor immediately below the turbines. Cooling water for the condensers was drawn from and returned to a nearby cooling pond 300 ft. square, via 9 in. cast iron underground pipes, the normal water level in the pond being some 4 ft. above the ground floor level of the power house. In 1931 public power supplies in duplicate became available and the old steam generating plant was removed. The two supplies, which were taken from different power companies to guard against failure of either supply were led into the power house at a pressure of 10·5 kV; H.V. and M.V. switchgear was installed along one side of the turbine floor and transformers were accommodated on the ground floor under the H.V. switchboard.

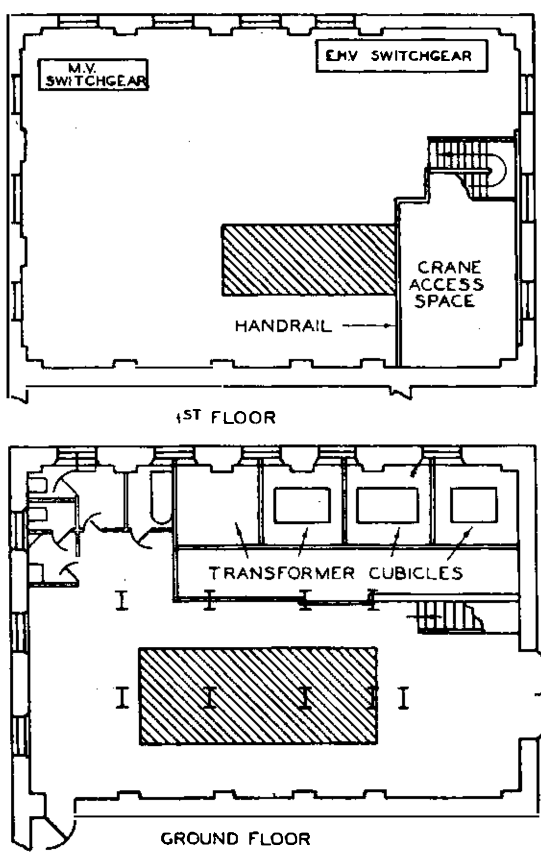


FIG. 1.—FLOOR LAYOUT.

In the course of time increasing demands on on company's system resulted in the power availabl at the radio station from that supply becomin inadequate, and this, coupled with the fact tha both of the other company's lines originated at th same switching station made it necessary to provid an emergency generating plant at the radio statio to safeguard the essential war-time services operate from Leafield from the effects of large-scale failure c public power supplies. The load conditions wer investigated and a specification for an oil engine driven generator set was drawn up, allowance bein made for some future increase in power demand.

The difficulty of obtaining building labour an materials at that time was most acute, so althoug from the A.R.P. aspect it would have been bette to house the engine set in a special building remot from the existing station buildings, the power hous (which was the only building in which any free spac existed) was examined to see if, by relatively simpl building modifications, the engine set could b accommodated therein. Floor plans of the pow house are shown in Fig. 1. It was decided that th generator set could be accommodated on a foundati block at ground floor level (shown hatched in Fig. by moving a number of stanchions supporting th turbine floor, and that adequate working room roun the top of the engine, and gantry crane access theret would be secured by simply cutting a sufficiently lar rectangular hole in the turbine floor (also show hatched in Fig. 1).

Load Conditions.

The supply feeds 3-phase full wave rectifiers v transformers, together with induction motors ar a number of condensers giving partial power fact correction. The short wave and long wave transmitte are accommodated in two separate buildings abo 100 yards from the power house. With the increa in load due to development, the original mediu voltage distribution system became inadequate ar a second sub-station, connected by high volta cable to the first, was installed in the short wa building, so that power for all buildings might l distributed from both substations simultaneousl The half-hour maximum demand was 540 kVA, b the consumption was observed to fluctuate at frequency of the order of 5 c/s between limits of 5 and 580 kVA, with extreme variations at interv of two or three seconds of 450-630 kVA. To allow f further development a maximum demand of 600 k was assumed and the load conditions were detailed the specification for the plant as follows :

Load fluctuations between 550 and 650 kVA 4-5 c/s.

Load fluctuations between 500 and 750 kVA at intervals of two to three seconds.

Possible load fluctuations between 350 and 950 kVA.

Power factor 0·9 lagging. Max. demand 600 kVA.

Choice of Plant.

In drawing up the specification for the plant and in the selection thereof, the following considerations were borne in mind.

(1) The plant must be thoroughly reliable.

(2) Quick starting after periods of idleness is facilitated by the adoption of a cold starting engine with starting air supplied to all cylinders (obviating barring round if the engine does not start at the first attempt), the priming of the engine with lubricating oil by gravity flow from an elevated tank, keeping the lubricating oil warm by the provision of thermostatically controlled immersion heaters in the oil sump, and the minimisation of valves, electrical controls, etc., requiring preliminary adjustment.

(3) Fuel costs, efficiency and depreciation by wear are relatively unimportant for plant required primarily for emergency generation, and in this plant it was possible to economise in capital expenditure and accommodation costs by the adoption of a supercharged engine running at a rather higher speed than usual for this size and type of direct generating plant.

(4) As the set is primarily required for use after failure of the public power supply, automatic battery lighting is necessary at the engine and electrical controls, the air compressor must be driven by a prime mover and the cooling water sytem should be independent of motor driven pumps.

(5) In view of the rapid fluctuations of the radio station load it was necessary for the sub-transient reactance of the alternator[1] to be as low as reasonably possible so that the voltage variations should not exceed ± 5 per cent., and for the cyclic irregularity of the engine to be limited by a flywheel of ample inertia.

(6) It was desirable that with the emergency generator supplying the station the distribution system should be operated normally, so an alternator generating at 10·5 kV was necessary.

(7) As regards the bulk storage of fuel, the major consideration was the possibility of considerable delay in delivery of fresh supplies (due to enemy action), and on this account it was decided to provide storage accommodation for a fortnight's supply of fuel.

Description of Plant.

The plant comprises a super-charged, 4-stroke, 6-cylinder, compression ignition, solid injection, oil engine of 900 B.H.P. running at 428 r.p.m. manufactured by Mirrlees, Bickerton & Day, directly coupled to a 625 kVA alternator manufactured by Metropolitan Vickers, generating at 10·5 kV and

[1] This is defined as the ratio of the R.M.S. open-circuit armature voltage of an alternator operating at no-load to the initial R.M.S. value of the fundamental A.C. component of armature current produced on sudden application of a short-circuit, and is the reactance which determines the variation of alternator voltage due to a rapidly fluctuating load.

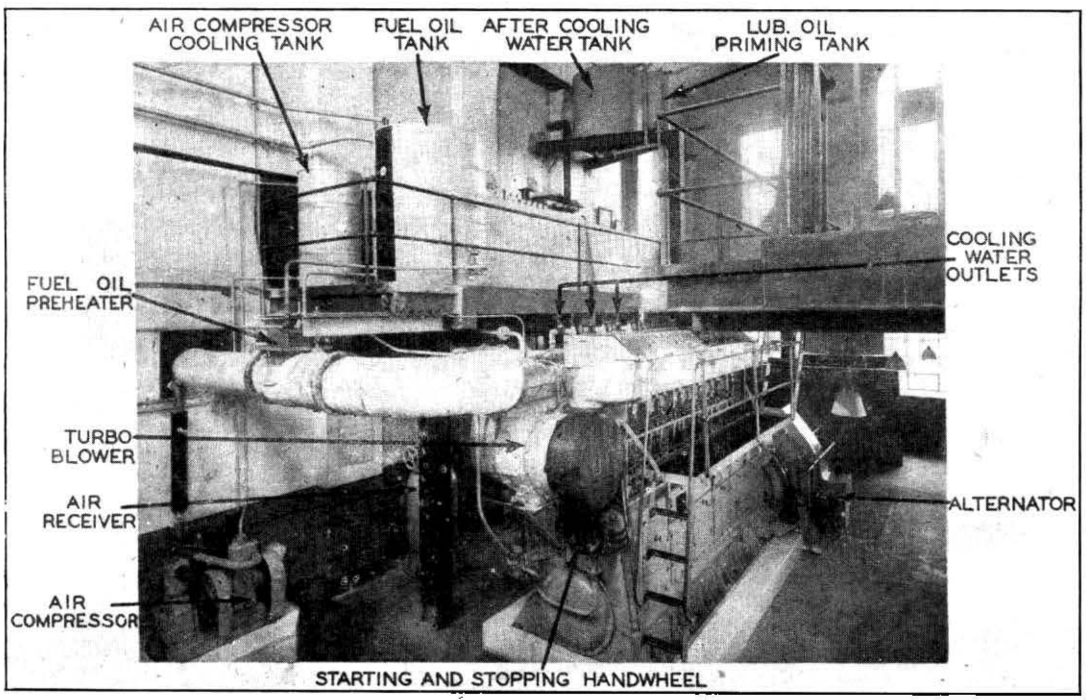


FIG. 2.—GENERAL VIEW OF GENERATING PLANT.

supplying power to the station system via switch-gear, also manufactured by Metropolitan Vickers. The generating plant is shown in Fig. **2** and the electrical control gear on the left of Fig. **3**.

through the pond. The hot water discharged from the engine is used in a fuel pre-heater in the exhaust pipe. Water for after-cooling of the engine is supplied from a 300 gallon overhead tank.

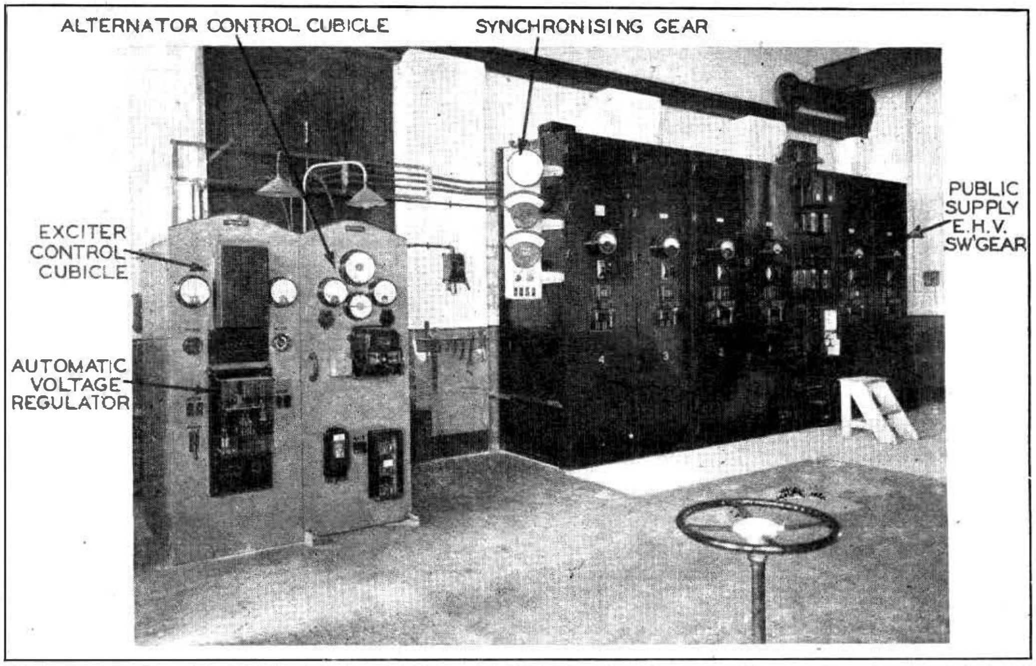


FIG. 3. ALTERNATOR CONTROL GEAR AND PUBLIC SUPPLY E.H.V. SWITCHGEAR.

The engine has a stroke of 19 in. and cylinder bore of 13¾ in.; the super-charging is effected by a Richardson Westgarth Brown Boveri turbo-blower which is driven by the exhaust gases. The engine is fitted with two exhaust manifolds (one for cylinders 1, 2 and 3 and the other for cylinders 4, 5 and 6) to avoid interaction between the cylinders, and both manifolds discharge into the impulse turbine of the super-charger. The fly-wheel weighs 2½ tons and is sufficient to reduce the cyclic variation due to the engine and load impulses to 1 in 400. Lubricating oil is contained in a 180 gallon sump at the generator end of the engine, and after being pumped through a Lolos strainer which removes all particles larger than 0·005 in. the oil is cooled and distributed to the crankshaft and big end bearings. The pistons are splash lubricated but uncooled. The engine can be primed with lubricating oil either by a semi-rotary hand-pump or by a special overhead priming tank. Cooling water is drawn from one of the 9 in. cast-iron pipes originally installed for the steam condensers and is circulated by a belt-driven centrifugal pump through the oil cooler and thence to the engine cylinder jackets and turbo blower. The water is discharged from the cylinder heads via throttle valves (at which points thermometers indicate the temperature of the water) into a water manifold connected to the return 9 in. cast-iron pipe. As the temperature of the cooling pond might fall nearly to freezing point, arrangements were made to expedite warming up and maintenance of a suitable temperature in the cylinder jackets and heads by recirculation of cooling water through the engine without passage

Compressed air for starting the main engine i stored at 300 lb. per sq. in. in a 10·9 cu. ft. receive charged by a petrol engine-driven air compressor Starting air is supplied to all cylinders by an automatic distributor valve.

Oil fuel is stored in bulk in two 6,600-gallo cylindrical steel tanks (7 ft. 6 in. diameter by 25 ft 6 in. long) which were installed alongside the coolin pond and connected by underground pipework to fuel transfer pump in the power house. The bull storage tanks were fitted with dip rod, filling, an breather pipes in the manhole cover, sludge drains an immersion heaters, and arrangements were made t enable the fuel transfer pump to draw oil from eithe bulk storage tank and force it into the other or int an overhead 10-hour service tank.

The engine is protected against failure of oil an water circulation by the following automatic shut down devices. If the lubricating oil pressure fall below normal a spring loaded piston in a chambe connected to the lubricating oil circuit travels distance proportional to the fall in pressure and i so doing first closes an alarm bell circuit and sub sequently renders the fuel pumps in the engine in operative if the oil pressure continues to fall. water flow indicator, to which are attached tw mercury switches, is fitted in the cooling water inle to the engine and if the water flow falls to a pre determined value one of the mercury switches close the alarm bell circuit; if the water delivery fal still further the other mercury switch operates a reli valve in the lubricating oil tripping gear, thus stoppin the engine.

The alternator is a 3-phase, star-connected, 60 c/s, 10·5 kV, 34·4 A, 625 kVA, 0·9 power factor, low reactance machine protected against phase and earth faults by Merz-Price circulating current equipment. The neutral ends of the phase windings are brought out in a cubicle housing one set of current transformers in the Merz-Price protective gear. The other set of transformers is fitted in the alternator control cubicle which also accommodates an oil circuit-breaker of 75 MVA breaking capacity, a kWh meter, ammeter, voltmeter, power factor meter and frequency meter. The outgoing side of this panel is cabled to the busbars of the H.V. switchboard. The exciter is rated at 186 V, 53 A, and the current delivered and voltage generated are shown by an ammeter and voltmeter provided on the exciter control cubicle. A hand-operated rheostat in the exciter shunt field circuit which provides manual control of the alternator output voltage, an automatic voltage regulator and a main field suppression switch are also provided in this cubicle. The field suppression switch as well as the main circuit-breaker are tripped under fault conditions by the Merz-Price gear.

Plant Layout and Building Work Involved.

Installation of the new plant involved some substantial alterations to the existing building. The turbine floor consisted of a concrete-filled steel grillage supported by stanchions from the ground floor and the removal of the middle part of this floor necessitated the shifting of some of the stanchions to new positions under the edge of the gallery formed by the turbine floor. The concrete was removed from the area necessary to provide working room round the upper parts of the engine, and as the main beams of the steel grillage were more than strong enough to support such weight as remained without help from the stanchions, which had been provided originally to support the turbines, these stanchions were removed. The excavation for the engine and alternator foundation block and for the new footings of the stanchions which had to be reinstated then proceeded; 60 cu. yds. of earth and the foundations for the original steam condensers were removed and used to cover the oil and sludge pipes from the bulk fuel tanks for the purpose of thermally insulating them. The stanchions were then bolted in their new positions to the main beams of the turbine floor, so that their feet hung clear in the footing excavations, and the concreting of these footings and of the engine alternator block was then carried out. The block was reinforced at the bottom, particularly in the vicinity of the fly-wheel pit, and to prevent transmission of vibration the block was insulated from the ground and the stanchion footings round its side by fibre board. When the concrete had set, the exposed steel grillage of the turbine floor was cut away and the edges of the hole were faired. The recovered joists from the turbine floor were used for the fabrications of tank and silencer supports.

Works Tests.

The engine was tested at the makers' works. The fuel consumption at various loads are given in Table 1.

TABLE 1.

FUEL CONSUMPTION DURING WORKS TEST.

	¼ Full Load	½ Full Load	¾ Full Load	Full Load	10% over Load
Lb/B.H.P.-Hr.	·442	·39	·375	·373	·379

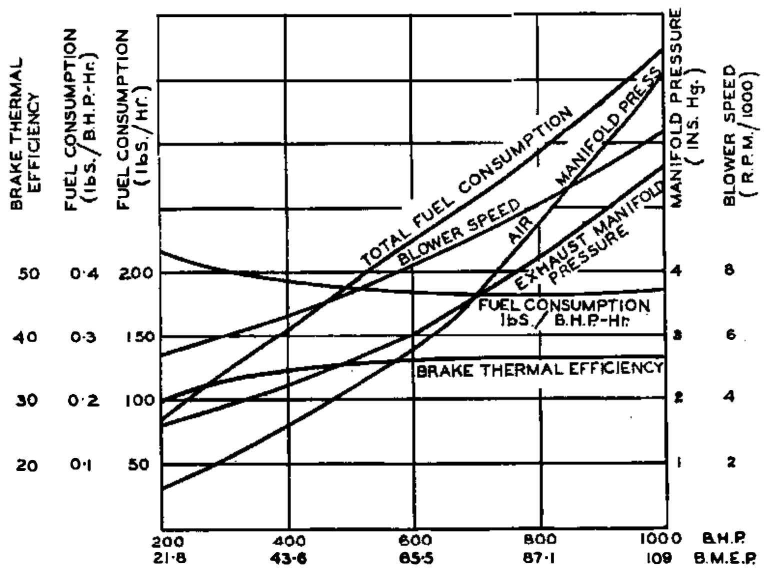


FIG. 4.—DIESEL ENGINE CHARACTERISTICS.

The results of the tests are presented in graphical form in Fig. 4. The governor spring was found to be too strong (a 5 per cent. rise in speed was recorded on removal of full load), so a weaker spring which approximately doubled the sensitivity without any sign of hunting resulting was substituted. The automatic tripping and alarm devices were not fitted for these tests.

Alternator and exciter tests (without a prime mover or load) were carried out as follows:—

(*a*) Resistance measurements.

(*b*) Open-circuit and short-circuit tests from which the excitation, voltage regulation, synchronous reactance and efficiency were determined. For these tests the machine was separately excited and was driven by its own exciter.

(*c*) Locked rotor and oscillographic tests for the determination of subtransient reactance.

(*d*) A 5-hour zero power factor run, the machine being run as a synchronous motor on no load and over-excited to give full load stator and rotor currents when supplied from an under-excited alternator, for the determination of temperature rises, rotor loss and stator leakage reactance on load.

(e) Open-circuit oscillographic test for voltage wave form.

(f) Insulation resistance tests.

(g) High voltage tests.

From these tests the regulation on full load at 0·9 power factor was found to be 12·4 per cent. and on full load at unity power factor 3·8 per cent. The synchronous reactance was 48·5 per cent. and the efficiency varied from 92 per cent. at half load to 97 per cent. at full load, 0·9 power factor or 98 per cent. at full load and unity power factor. Temperature rises were within the B.S. limits. The subtransient reactance was determined by the locked rotor test and the short-circuit application test. For the first, the rotor was short-circuited and locked in various positions while a 50 c/s voltage was applied across two phases of the stator, and the resulting stator current and rotor current were plotted against the applied voltage. For the position in which the rotor current was maximum the ratio of th applied voltage per phase to the armament current give the reactance per phase which was found to be 17·8 Ω or 10·1 per cent. For the second test short-circuit were suddenly applied to the stator when generating 1,750 and 3,500 V. The initial A.C. componen of current in each phase was determined by producin the envelopes of the current waves as recorde on oscillograms (Fig. 5), back to the instant o short-circuit. The reactance was then found fo each phase by taking initial voltage-current ratio which gave averages of 10·1 per cent. for the 1,750 V condition and 9·3 per cent. for the 3,500 V condition the latter figure being lower owing to saturation ir the iron circuit. The wave form, insulation resistanc and high voltage tests were all satisfactory.

Tests on Site.

After installation at Leafield, full load and fractiona load tests were carried out using steady resistanc loads, followed by a week's run on the normal statio load. For the steady resistance loads 24 Cressal resistance mats, each capable o dissipating 25·5 kW at 10·5 kV, wer suspended outside the power house i such a manner that ¼, ½, ¾ and ful load could be applied by simple bolte connections, the load being connecte to the alternator control cubicle b temporary cabling. Before carrying ou the load runs the performance of th auxiliary equipment was checked particularly the number of starts o the main engine which could be mad without recharging the air receiver This was found to be 10, but as th starts were made consecutively and th engine was not absolutely cold, th figure can be taken as no more tha indicative of the fact that the ai receiver capacity is quite adequate t cater for difficult starting condition e.g. extremely cold weather. Durin the load runs, the fuel consumption were determined with the aid of a stop watch and weighing machine; th B.H.P. of the engine for the variou loads was found from the know efficiency of the alternator, and th kWh meter (which was checked agains the kW meter). The following obse vations on the engine were made a half-hourly intervals: Cooling wate inlet and outlet temperatures, exhaus temperatures, lubricating oil pressur and temperature (in and out of th oil cooler), supercharger speed, air an exhaust manifold and exhaust pip pressures, exhaust temperatures at th input of the supercharger and fuel pum rack readings. The water circulatio through the pond was occasionall determined with a V-notch, and cylinde pressures (compression and maximum were taken for each load conditio

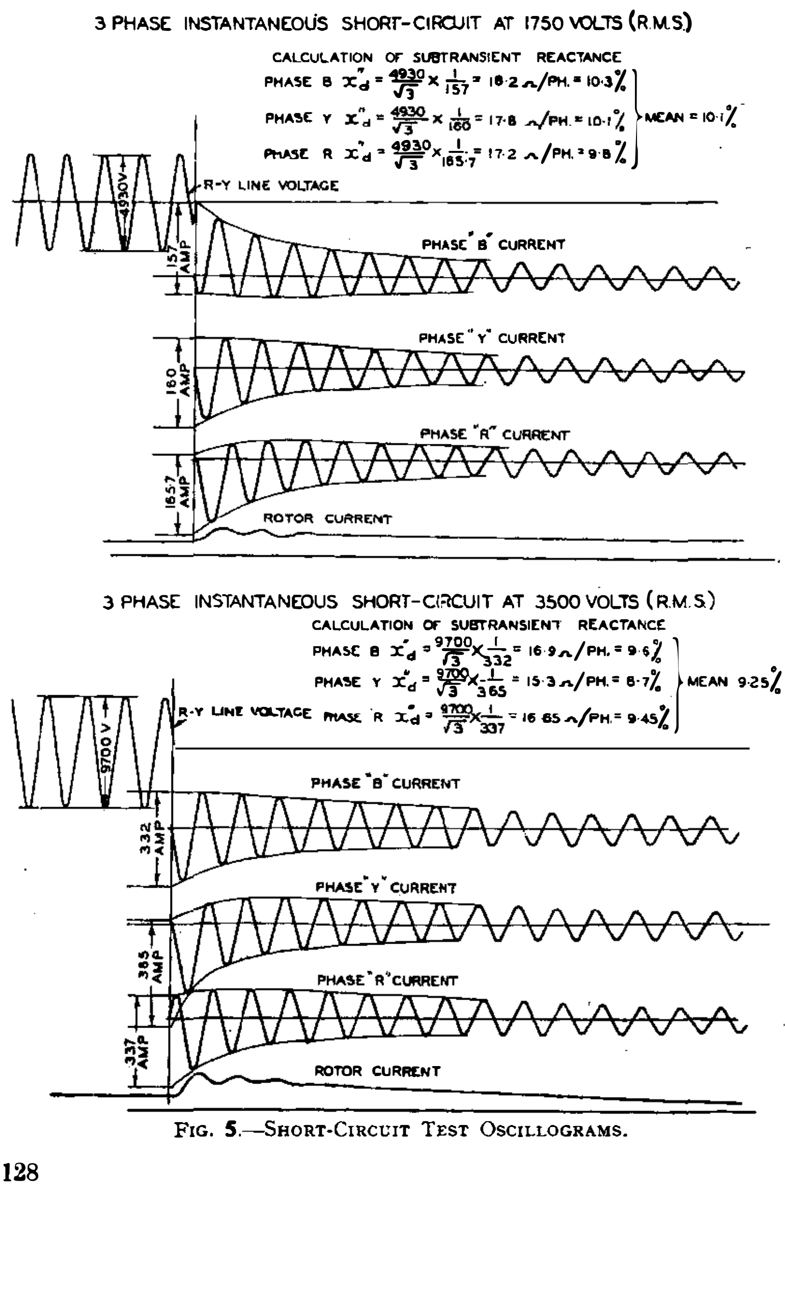


FIG. 5.—SHORT-CIRCUIT TEST OSCILLOGRAMS.

The results of the site tests on the engine were practically the same as those for the works test.

On the electrical equipment the voltage and current in each phase, the kWh, frequency, exciter current and voltage, were recorded. at half-hourly intervals. Governor and regulation tests on fractional and full loads were carried out with the automatic voltage regulator in operation, by tripping and re-applying the loads. The speed variation on removing full load was 6 per cent. maximum and 4 per cent. steady, and the voltage variations 8 per cent. maximum (settling to 1 per cent. steady) as given by the switchboard meters, but these maximum figures are subject to the effects of meter overswing. The stability and sensitivity of the Merz-Price equipment was also checked, and it was found that the relays would not operate unless the current due to a fault outside the zone of protection rose to at least 50 times full load current. As the alternator is solidly earthed, at least 90 per cent. of the stator windings are protected against phase or earth faults within its protected zone.

At the conclusion of the steady load tests the engine adjustments, i.e. crankshaft deflections, valve settings and tappet clearances were measured, and arrangements were then made to take the station load for a week by transferring the temporary cabling from the resistance loads to the H.V. busbars and checking the phase rotation of the alternator by running one of the station motors. Owing to delay in the provision of synchronising gear, the changeover from the public power supply to the alternator necessitated a station shut-down at the commencement and end of the week's run. Throughout this run test readings were taken at hourly intervals and occasionally the exhaust gases were analysed with Orsat apparatus, which indicated that no CO was present, i.e. combustion was complete, and that the air used was approximately four times that theoretically required for complete combustion of the fuel. At the end of the week's run the rotor and stator temperatures and the insulation resistance of the electrical equipment were taken, all of which were satisfactory. The engine adjustments were re-measured and were found to be only slightly different from those taken before. From the results of the week's run it was found that at slightly more than half full-load the heat balance for the engine was 36.5 per cent. to work, 26·5 per cent. to cooling and 37 per cent. to exhaust.

Generally the results indicated that the engine and alternator are capable of meeting some considerable increase over the present station demand, especially if the power factor is corrected. The limiting factors on power output from the set are the rotor winding temperatures and exhaust temperatures at the supercharger inlet. The output might, therefore, be increased to some extent by forced air cooling of the alternator and water cooling of the exhaust manifolds.

Cabling Operations — A Note from Germany

The control of Posts and Telecommunication activities in Germany is exercised by a group of officers practically all of whom are drawn from the Post Office, and from time to time there arise interesting comparisons between methods employed by the Germans and those used in Great Britain.

One such example was noticed recently in cabling operations being undertaken in a large town, where a cable approximately the same as the British 300 pair 20 was being withdrawn and drummed for re-laying in another place. The procedure was interesting because it provided for the drumming of the cable in one operation with its recovery. The cable was first pulled from the duct sufficiently far to enable it to be manhandled on to a nearby drum, to which it was secured by means of a steel stocking. To the remote end of the drum barrel was connected a steel hawser already wrapped around the barrel as many times as was necessary to rotate the drum sufficiently to coil the whole length of cable. The steel hawser was confined to one end of the drum by steel lugs bolted to the barrel. The barrel itself, incidentally, is specially reinforced to withstand the stresses resulting from the pull. The steel hawser was run over the winch drum in the usual fashion. Thus when the winch was operating it rotated the drum which in turn both pulled the cable from the duct and coiled it on to the barrel of the cable drum.

Referring to Fig. 1, the pulling winch is hidden behind the drum and it will be appreciated that the cable is being drawn from a duct in the foreground.

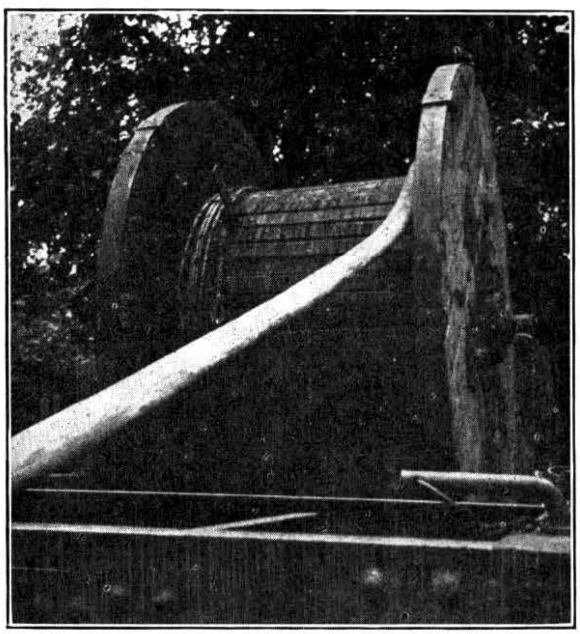


FIG. 1.

The above method is used extensively by the Reichspost and is stated to give excellent results.

H.O.E.

Some Aspects of Earthing

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The behaviour of currents flowing in the earth as affected by soil resistivity, shape and size of electrode is discussed and some of the more important formulæ for the earth electrode resistance are derived.

Introduction

THE practical and theoretical aspects of earthing as applied largely to the use of the earth for the earthing of electricity supply systems have, in recent years, been the subject of considerable investigation and much information on the subject has been published.[1,2] As a result important changes in the practice of earthing have taken place not only in the electricity supply industry but also in the field of telecommunications. It is proposed in this article to give a brief account of some of the fundamental considerations which arise.

Earthing is one of the oldest practices, dating back to the days when scientific experimenters showed that by touching a charged body with the finger the charge leaked to earth. From the commercial aspect the use of the earth as a return path for telegraph circuits and, indeed, for power circuits was common practice for many years. Nowadays the earth is used mainly for fixing the neutral point of power generating or transmitting systems and to provide against the risk of shock accidents due to leakage from the system. The uses of the earth for screening high frequency communication circuits, for completing the signalling path and for protection against lightning are well known.

In general, what is required is an efficient connection with earth, and numerous rules and regulations exist which specify generally or in detail how this can be achieved. The popular opinion hitherto held on the subject seems to have been based on the idea that owing to the great dimensions of the earth it was necessary only to make good contact with the earth and the result would be a negligibly low resistance. Investigations have shown that this is by no means the case.

It is usual to regard the total resistance of the path to earth via an earth electrode as consisting of three separate parts :—

(*a*) The resistance of the connecting leads to the earth electrode itself.
(*b*) The contact resistance between the metal of the earth electrode and the surrounding soil.
(*c*) The resistance of the surrounding soil.

(*a*) and (*b*) are relatively small in value and practically the whole of the resistance to flow of current through an earth electrode is to be found in the soil immediately surrounding the earth electrode.

Soil Resistance.

The conductivity of the materials of which the earth's crust is mainly composed is very low compared with the high conductivity of metals. Two constituents, aluminium oxide and silicon oxide, are actually very good insulators. The soil is, however, electroly in character and the resistance depends largely up the character of the electrolyte present. If a s is completely dried out it has such a high resistivi as to render it quite useless for earthing. T resistivity of the moisture in the soil is determin by the nature of the soluble salts present and by t concentration of the salts which depends upon t rainfall, permeability of the soil, evaporation and t rate of removal by vegetation. It is also depende on the temperature and the bacteriological activi in the soil which varies with the time of year and affected by the nature and degree of vegetatic Frozen soil has a very high resistivity and it important to bury electrodes below the frost line.

There is a full account elsewhere of the characteris influence of the various soils on the resistivity,[1,2] b the following summary is intended to give a gene indication.

The lowest resistivity values are found in s marshes, but low values are sometimes found made-up ground containing ashes and cinders, etc. values as low as 500 ohm-cm. have been obtain Next in order come clay soils, including loams, whi range between 1,000 and 15,000 ohm-cm. Dry lo on the surface cannot effectively be used for earthi and the electrodes must be buried below it. Pu sand or gravel has a very high resistivity and shou not be used for earthing without prior tests to veri the resistivity value. The resistivity of the soil mountainous districts is often very high, exceedi 30,000 ohm-cm. This is generally due to t sub-strata of rock underlying a relatively thin a discontinuous layer of wet peaty soil from whi soluble salts have often been largely dissolved by t heavy rainfall. The purity of mountain streams probably due to the same cause. Soils of a roc nature have a very high resistivity and only t superficial layer should be used for earthing. Chal limestone and other such materials present serio difficulties for earthing.

Resistance of an Earth Electrode.

The resistance of an earth electrode has theoretica no finite value and increases as an increasing mass surrounding soil is taken into account. The variati of resistance with distance from the earth electro is of the form shown in Fig. 1a.

The resistance increases with distance from t earth electrode, but the rate of increase decreas After a certain distance the resistance reaches practically constant value, and this value is taken the resistance of the earth electrode. It is eas seen that this is so if it is visualised that the curre spreads out in *all directions* from the earth electro

The whole area of the ground (round an ea electrode) within which a voltage gradient, measu

[1] *J.I.E.E.* Vol. 87, p. 357.
[2] *Electrical Engineering*, Vol. 64, p. 1.

able with ordinary commercial instruments, exists when the electrode is being tested is known as the resistance area. In homogeneous soil a similar voltage gradient would be found to exist within the hemisphere under the resistance area as defined above.

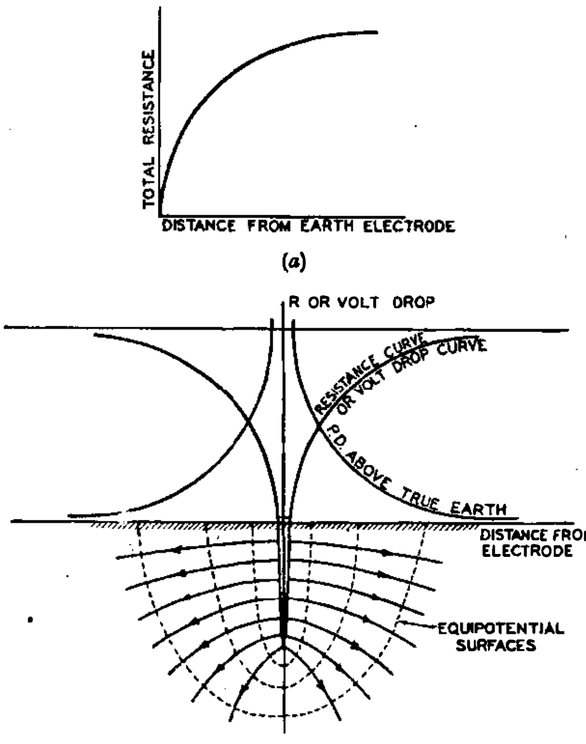


FIG. 1.

An earth electrode is in effect a point at which a potential may be applied to the earth in the vicinity of the electrode itself, the resultant potential gradient being the product of the rate of increase of resistance and the current flowing to earth. Thus when a potential is applied to an earth electrode the ground surface within the resistance area is raised in potential. Figure **1** (*b*) shows how the resistance from a rod electrode to a given point varies with the distance of the point from the electrode. This curve is also the curve of the drop in potential to any point from the electrode. The curve showing the potential above true earth at any point is obtained by subtracting the ordinates of the volt drop curve from the potential of the electrode above true earth. The slope of either of these curves (positive in the one case and negative in the other) is the rate of change of potential or the "potential gradient." Ground surface potentials have greater significance in the operation of electricity supply systems than in telecommunications because of the high value of current likely to circulate via the system earth electrode. Ground surface potentials may present a danger to life and this may well be the explanation of occasional and otherwise unaccountable shocks and fatalities to animals. They may arise through earth leakages on inadequately earthed electricity supply poles. They may also appear in the vicinity of objects such as trees which are struck by a lightning discharge. The liability of cattle to congregate under trees or near electricity supply poles exposes them to danger because the fore and hind feet are sufficiently separated, having regard to the voltage gradient on the ground to present serious danger of shock.

Effect of Shape of Electrode on Potential Gradient.

To obtain an equation for the potential gradient it is convenient first to consider the case of a spherically shaped electrode, which is fairly representative of any compact form. The lines of current flow through the earth may be regarded as the same as the electrostatic lines of force which would exist if the earth were considered as a dielectric and the electrode, combined with its image above the earth's surface, treated as a condenser in free space. The formula connecting the resistance to flow of current away from an electrode buried in the surface of the earth and the capacitance of the electrode with its image is

$$R = \frac{\rho}{2\pi C}$$

where R = resistance,
ρ = specific resistance of the soil or soil resistivity,
C = the capacitance in free space.

When the electrode is a hemisphere, this, combined with its image, forms a complete sphere and the capacitance of a sphere in free space is equal to its radius. Hence for a hemispherical electrode of radius r the resistance is

$$R = \frac{\rho}{2\pi r}$$

Measured to a distance D

$$R = \frac{\rho}{2\pi}\left[\frac{1}{r} - \frac{1}{D}\right]$$

If R is plotted against D a hyperbola is obtained (Fig. 2).

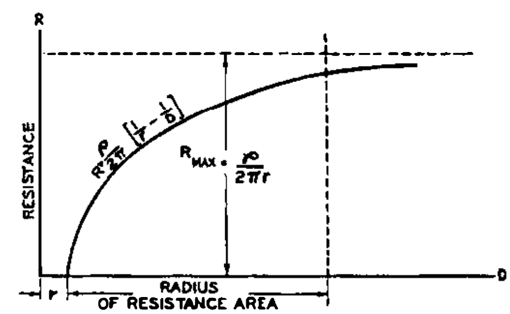


FIG. 2.

The curve is asymptotic to the line $R_{max.} = \rho/2\pi r$ and the value of D at which R almost reaches this value is the radius of the resistance area (see above for definition) at which, in practice, R reaches the steady finite value $\rho/2\pi r$. For example, suppose a hemispherical electrode of radius **100** cm. be buried in the surface of the earth where the soil resistivity is **10,000** ohm-cm. Its resistance to earth will be

$$\frac{10{,}000}{2\pi 100\text{cm}}\text{ ohm-cm.} = 16 \text{ ohm.}$$

If r is increased n times the total resistance is decreased in the same ratio and the distance from the electrode at which practically the whole of the potential drop will have occurred is increased n times.

Let V and I be the potential and current respectively applied to an hemispherical electrode. Then

$$I = \frac{V}{\rho/2\pi r} = \frac{2\pi r V}{\rho}$$

The potential drop between the electrode and a point at distance D will be

$$\frac{2\pi r V}{\rho} \times \frac{\rho}{2\pi}\left(\frac{1}{r} - \frac{1}{D}\right) = V - \frac{rV}{D}$$

so that the actual potential above true earth at distance D is given by

$$\frac{rV}{D} \quad \ldots\ldots\ldots\ldots (1)$$

The potential gradient at distance D is the first differential of this expression, which is

$$-\frac{rV}{D^2} \quad \ldots\ldots\ldots\ldots (2)$$

From these expressions it will be seen that the potential gradient, and hence the size of the resistance area, are independent of the resistivity of the soil. It will furthermore be apparent that the ratio of the potential drop up to any point to the potential across the whole of the resistance is also independent of the resistivity of the soil, and depends solely on r, i.e. the dimensions of the electrode and for a given size and shape of electrode the shape of the resistance curve is fixed.

In general, the total resistance of any earth electrode is determined partly by the dimensions of the electrode and partly by the specific resistance of the soil. It is conceivable that an earth electrode of small dimensions may have quite a low resistance due to the low resistivity of the soil, but the potential gradient may be high. On the other hand, an earth electrode of large dimensions may have a high resistance due to the high soil resistivity but the potential gradient may be low due to the large dimensions.

Electrodes in Parallel.

If two or more electrodes are buried in the ground and connected in parallel their total resistance does not necessarily follow the usual law for resistances in parallel. Considering the case of the hemispherical electrode the voltage from the surface of the sphere of radius r to a distance D is

$$E = \frac{\rho I}{2\pi}\left[\frac{1}{r} - \frac{1}{D}\right]$$

Suppose two spherical electrodes of equal dimensions to be at a distance 2x apart, centre to centre, and each carrying a current I (Fig. 3).

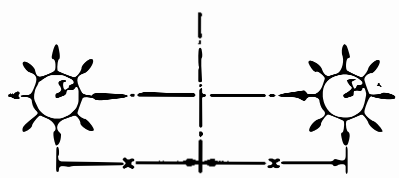


FIG. 3.

The potential at the surface of each sphere is dependent upon its radius and the mutual potential due to the distant sphere. This is determined by the distance 2x. The total potential is therefore

$$E_{total} = \frac{\rho}{4\pi}\left(\frac{I}{r} + \frac{I}{2x}\right)$$

$$= \frac{\rho I}{4\pi r}\left(1 + \frac{r}{2x}\right)$$

But each sphere carries a current I, therefore the total resistance is

$$R_{total} = \frac{E_{total}}{2I} = \frac{\rho}{4\pi r}\,\frac{1}{2}\left(1 + \frac{r}{2x}\right) \ldots\ldots (3)$$

If x is infinite then

$$R_{total} = \frac{\rho}{4\pi r}\,\frac{1}{2}$$

and the resistance of the two electrodes in parallel would be half the resistance of one, as normally applies for resistances in parallel.

If x = r then the combined resistance would be

$$\frac{\rho}{4\pi r}\,\frac{3}{4}$$

Taking the practical case of two rod electrodes (Spikes, Earth, No. 2) in parallel, the relation between the measured percentage resistance of one electrode with the distance apart is as shown in Fig. 4.

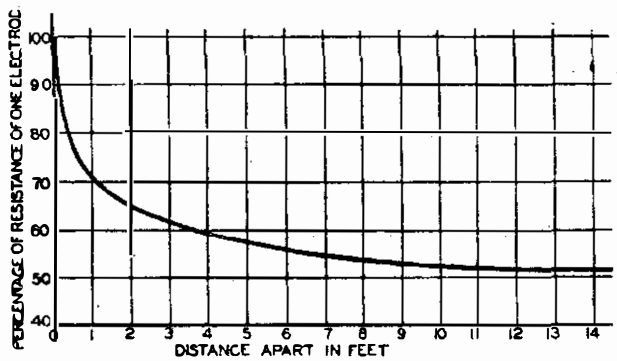


FIG. 4.

As an example, the joint resistance to earth of two rods, one foot apart, is 70 per cent. of that of one rod.

Depth of Electrode.

To examine the effect of the depth to which an electrode is buried consider the arrangement shown in Fig. 5. This may be regarded as half that of Fig. 3.

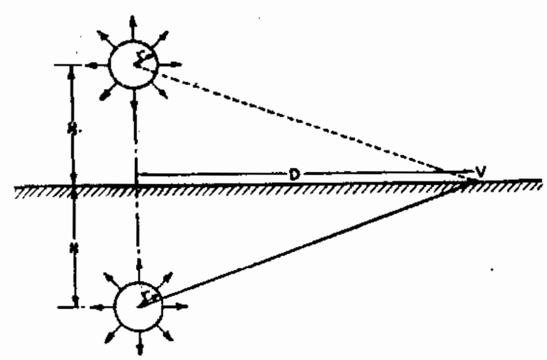


FIG. 5.

The resistance of the single electrode buried to a depth x will be twice that obtained for the two electrodes separated by distance x.
i. e.

$$R_{\text{sphere}} = \frac{E}{I} = \frac{2\rho}{4\pi r}\,\frac{1}{2}\left(1+\frac{r}{2x}\right)$$

$$= \frac{\rho}{4\pi r}\left(1+\frac{r}{2x}\right) \qquad (4)$$

If $x = r/2$ the resistance becomes $\rho/2\pi r$ as for a hemispherical electrode.

For greater values of x the resistance diminishes but, considering again the practical case of a rod electrode, the measured values of resistance and conductance plotted against depth are as shown in Fig. 6.

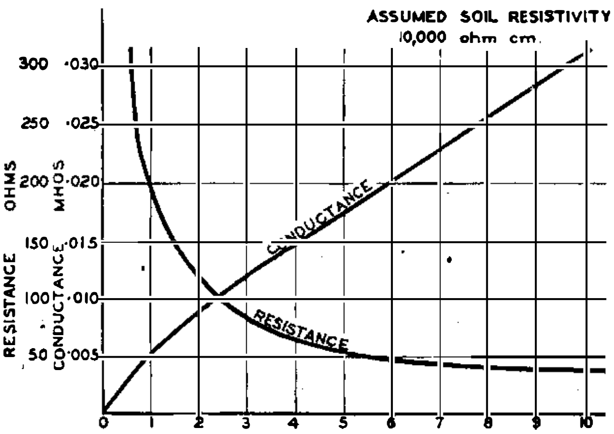


FIG. 6.

Rod Electrodes.

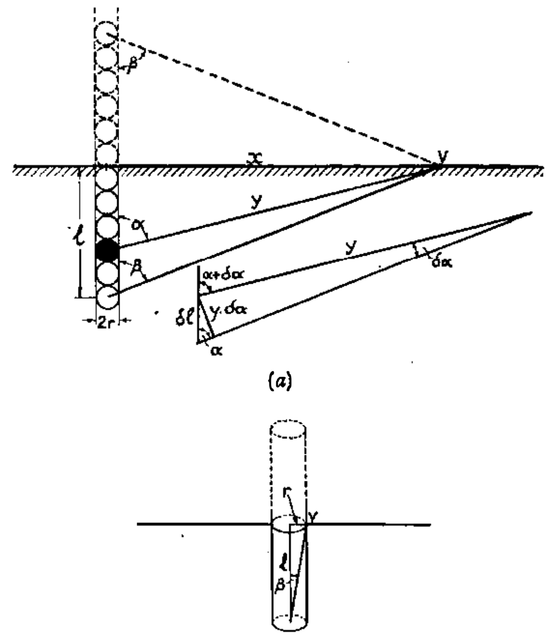
So far the theoretical case of a spherically shaped electrode has for convenience been considered. A spherical electrode is not, however, suitable for practical purposes; the common practice is to use rod electrodes which can be driven into the soil with relative ease and without the need for excavation.

Suppose an electrode to be in the form of an infinitely long rod of radius r. The earth resistance per unit length calculated to a distance D is

$$\frac{\rho}{4\pi}\log_e\frac{D}{r}$$

The resistance-distance curve for this expression is logarithmic and does not flatten out so rapidly as a hyperbola and the potential gradient is proportional to 1/D. The practical case is, however, a rod of short finite length with a small cross-section compared with its length. There is no exact formula for the earth resistance of such an electrode and it is necessary to use approximations. One approximation is to divide the rod into a large number n of spherical elements, and if l is the length of the rod buried in the ground let $l/n = \delta l$. If the total current passing through the rod to earth=I, each element will carry I/n. If y is the distance between any element and the ground surface at distance x and α is the angle between y and the axis of the rod (Fig. 7*a*)

$$\sin\alpha = y\,\frac{\delta\alpha}{\delta l}$$



(*a*)

(*b*)

FIG. 7.

The potential δV of every element is by analogy with the case of the spherical electrode,

$$\delta V = \frac{\rho I}{4\pi n.y.}$$

and by substitution

$$\delta V = \frac{\rho I}{4\pi l \sin\alpha}\cdot\delta\alpha$$

If the limiting angle $\alpha = \beta$ the voltage in the mid-plane of the rod due to n spherical elements below the ground surface and assumed spherical elements above the ground surface may be deduced by the method of images. Thus

$$V = \frac{\rho I}{4\pi l}\int_{+\beta}^{-\beta}\frac{\delta\alpha}{\sin\alpha} = \frac{\rho I}{2\pi l}\log_e\left(\cot\frac{\beta}{2}\right)$$

The potential V at the surface of the rod is equal to the voltage of the electrode, and it can be seen from Fig. 7*b* that if the radius of the rod is small compared with its length

$$\cot\frac{\beta}{2} \doteqdot \frac{2l}{r}$$

$$R_{\text{rod}} = \frac{E}{I} = \frac{\rho}{2\pi l}\log_e\frac{2l}{r} \qquad (5)$$

This result would be true if the current density leaving the rod and passing into the earth were uniform over the length.

Another approximation is to treat the rod as a charged body with the charge uniformly distributed over the surface and to calculate the average potential of the rod due to this charge. The capacitance is then deduced from this average potential and the total charge and from this the following formula is obtained for the earth resistance :—

$$R = \frac{\rho}{2\pi l} \log_e \left(\frac{4l}{r} - 1\right) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (6)$$

It is evident from a consideration of the two formulæ that (6) will always give lower values than (5), the difference depending on the ratio l/r. For instance, with a rod 6 ft. long and 2 in. diameter formula (6) gives a value 6·1 per cent. less than equation (5). With a rod 10 ft. long and 1½ in. in diameter the difference is 5·4 per cent. These errors are not very important in a calculated earth resistance. In any case, test of the formulæ is not very easy, since the specific resistance of the earth is not uniform and errors are introduced by its variation.

Strip Electrodes.

Where rod electrodes are used for an earth electrode system the connecting leads must be laid in a trench. If the nature of the soil or substratum makes it impossible to drive the rods, the connecting leads instead of the rods may be used as a strip earth electrode system provided they are of sufficient dimensions to produce the required result.

The resistance of a strip electrode is given by

$$R = \frac{\rho}{250l} \log_{10} \frac{216l^2}{wt} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (7)$$

Where R = resistance in ohms.
ρ = soil resistivity in ohm-cm.
t = depth of burial in feet.
l = length of electrode in yards.
w = width of electrode in inches.

Fig. 8 shows the variation of resistance with length

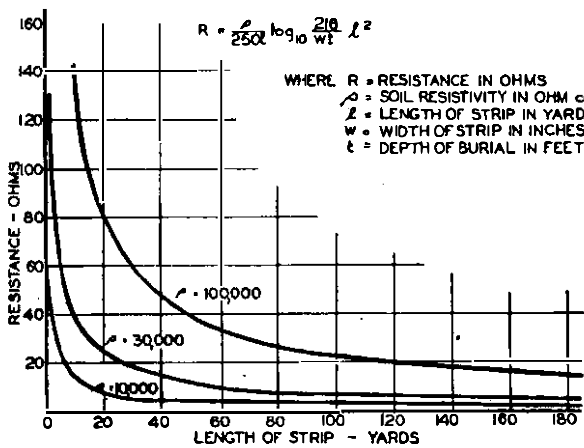


FIG. 8.

for an electrode consisting of a lead strip 2 in. wide buried to a depth of 18 in. in soils of various resistivities. The curves show that there is not much to be gained by laying long lengths of strip. The desired resistance can generally be reached by laying several shorter lengths, viz. 50–80 ft., provided the strips are well separated from each other.

Measurement of Soil Resistivity.

The formulæ for the earth resistance of the various types of electrode can be used if necessary in the design of a specific earth electrode system, but there is the difficulty that large variations exist in resistivity values in any one soil and reliance cannot be placed on tabulated values or on the values shown on the earth resistivity map prepared by the Electrical Research Association since these values were obtained for considerable depths and would not apply. There is, however, the choice of direct measurement of the soil resistivity, using a 4-terminal Megger Earth Tester or an indirect method using a trial rod electrode; measuring the earth resistance of the rod by the usual Fall of Potential method and determining the resistivity of the soil by substitution in equation (5).

With the 4-terminal Megger Earth Tester four electrodes are driven into the soil at equal intervals "a" in a straight line, and a known current passed between the outer electrodes, the potential across the inner pair being measured. If the electrodes were buried in the soil to such a depth that they could be regarded as placed in a conductor of infinite size it would be possible to derive an expression for the specific resistance of the soil in terms of the potential drop across the inner conductors. In practice, however, the electrodes are buried at shallow depth, but nevertheless the theory of the infinite conductor can still be applied if the earth's surface is regarded as a neutral plane of perfect conductivity with the "a" point electrode buried at depth "b" and its image above the earth's surface. This gives the formula

$$\rho = \frac{4\pi a R}{1 + \frac{2a}{\sqrt{a^2+4b^2}} - \frac{2a}{\sqrt{4a^2+4b^2}}}$$

where R is the resistance between the centre electrodes as given by the measured potential drop.

When measuring with the Megger Earth Tester "b" is very small in comparison with "a" so that the formula simplifies to

$$\rho = 2\pi a R \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (8)$$

Conclusion.

The ground under the surface of the earth is by no means homogeneous and this makes a rigorous analysis of the distribution of currents very difficult if not impossible. Further difficulties are encountered due to random changes brought about by weather conditions, including rain and frost and other temperature changes. It is practicable, however, to design an earth electrode system which will be suitable for a given site and within reasonable limits will be of the required resistance value, provided that the soil resistivity value is verified by direct or indirect method in all cases of uncertainty.

The author desires to express his thanks to his colleagues in the Construction Branch, Engineer-in-Chief's Office, who have made valuable suggestions in the preparation of the article, and in particular to Messrs. J. P. Harding and E. S. Swain. Thanks are also due to Messrs. V. Hall and R. Hunter, of the Bradford and York Areas respectively for assistance given during experiments in the field.

Road Haulage Service for Engineering Stores

Thursday, the 24th July, 1947, saw the commencement of a new phase of activity of the P.O. motor vehicle fleet. This was in the form of the inauguration of a country-wide road haulage service to effect door to door delivery of the bulk of the engineering stores which had, previously, been despatched by rail. The new service results from a decision by the Lord President of the Council that, in consequence of the serious shortage of railway goods rolling stock, Government Departments should arrange to carry as much goods traffic as possible by road to relieve the railways. The Post Office drew up a plan, which received Treasury approval, to increase its motor vehicle holding to meet this new requirement.

During the year 1946 some 118,000 tons of engineering stores were conveyed by rail from contractors' works to destinations throughout the country. This tonnage was made up approximately as follows :—

Ducts ..	.. 38,000 tons
Poles ..	.. 10,000 tons
Cable ..	.. 15,000 tons
Other stores	.. 55,000 tons

The types of traffic to be transferred from rail to road are broadly as follows :—

(*a*) Carriage of engineering stores (except poles, for which special rolling stock is expected to remain available) from contractors' works direct to Stores Dept. depots, section stocks, works sites, etc.

(*b*) Engineering stores now despatched from Stores Dept. depots by rail will be carried on additional Stores Dept. vehicles over the Stores Dept.'s scheduled routes. Onward traffic from the terminals of these routes will also become road-borne as far as possible.

(*c*) Recovered stores and returnable empties now sent by rail will be delivered by road as far as practicable.

A special goods haulage pool was formed and is being operated by the Chief Motor Transport Officer, Engineer-in-Chief's Office, to deliver stores ex contractors' works and to convey returned stores and empties. Fig. 1 shows the inauguration of this service between London and Birmingham on the 24th July.

The vehicles for this service range from 3- to 10-ton payload capacity and were obtained from ex-Service surplus vehicle depots. After having the chassis thoroughly reconditioned to secure reliable service on the arduous duties awaiting them, the bodies were modified and reinforced as necessary and repainted in an attractive and serviceable green colour.

Some idea of the problems to be faced may be gained from the following brief outline of the production centres for engineering stores of various kinds :—

Ducts are produced largely in the Midlands, other producers being situated in Dorset, South Wales, Lancashire and Yorkshire.

Wire is produced mainly in London, Hampshire and Lancashire.

Kiosks and ironwork are produced in the main in Scotland.

A single central Depot for the road haulage pool would therefore not meet the requirements, apart from the desirability of close liaison with the Stores Dept. depots in London, Birmingham and Edinburgh, and with consignees, as to detailed haulage requirements. The road haulage pool will therefore operate from several centres throughout the country. As indicated above, two centres are already open in London and Birmingham. In both these cases highly suitable accommodation has been acquired ; at Birmingham a huge modern factory shed is being shared with the Stores Dept. and the Factories Dept., and the London fleet is based on the Palace of Engineering at Wembley. The Liverpool depot should be open by the time this article appears in print and sub-depots will open in due course in Renfrew and Bristol. R. M.

FIG. 1.—POST OFFICE GROUP AT OPENING OF WEMBLEY DEPOT, INCLUDING THE ENGINEER-IN-CHIEF, DIRECTOR OF TELECOMMUNICATIONS, CONTROLLER-STORES DEPARTMENT AND CHIEF MOTOR TRANSPORT OFFICER.

Notes and Comments

Roll of Honour

The Board of Editors deeply regrets to have to record the deaths of the following members of the Engineering Department :—

Birmingham Telephone Area	Neale, P. A.	Skilled Workman, Class II	Sgt., R.A.F.
Edinburgh Telephone Area	Butchard, J. S.	Skilled Workman, Class II (B)	Signalman, Royal Signals
Leeds Telephone Area	Stead, P.	Skilled Workman, Class II	Sergeant, R.A.F.
London Telecoms. Region	Price, S. W.	Unestablished Skilled Workman	L.A.C., R.A.F.
Middlesbrough Tele. Area	Ryder, T. K.	Skilled Workman, Class II (A)	Sub-Lt., Fleet Air Arm
Plymouth Telephone Area	Angove, T. A.	Skilled Workman, Class II	Private, D.C.L.I.
Plymouth Telephone Area	Trevethan, R.	Unestablished Skilled Workman	Sergeant, R.A.F.
Southampton Telephone Area	Gatehouse F. W. G.	Skilled Workman, Class II (A)	Signalman, Royal Signals

Service Honours

The Board of Editors has learnt with great pleasure of the honours recently conferred upon the following members of the Engineering Department :—

Brighton Telephone Area	Borrer, R. W.	Skilled Workman, Class II	Corporal Royal Signals	Medaille de la Reconnaissance Français
London Telecoms. Region	Towey, H. O.	Skilled Workman, Class II	Corporal Royal Signals	British Empire Medal
Swansea Telephone Area	Griffiths, H. F.	Skilled Workman, Class II	Wt. Offr., Class II, Royal Signals	Order of Orange Nassau

Birthday Honours

The Board of Editors offers its congratulations to the following members of the P.O. Engineering Department honoured by H.M. the King in the Birthday Honours List.

Bradford Telephone Area	Taylor, W. C.	Technician	British Empire Medal
Cambridge Telephone Area	Fall, W. H.	Technician	British Empire Medal
Engineering Department	Booth, C. F.	Assistant Staff Engineer	Officer of the Order of the British Empire
Peterborough Telephone Area	Greetham, H.	Skilled Workman, Class I	British Empire Medal
Welsh and Border Counties Region	Field, A. H. G.	Assistant Engineer	Member of the Order of the British Empire

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Mr. T. F. Lee, O.B.E.

In addition to the Post Office personnel included in the Birthday Honours List this year, we were pleased to see the name of Mr. T. F. Lee. Mr. Lee as Secretary of various telephone equipment manufacturers' committees has been largely responsible for the good relations which exist between the Post Office and its principal suppliers of telecommunications equipment and we are happy to note that his good work in this connection has been recognised by the award of an O.B.E.

Telephone Reconstruction in Poland

The Polish authorities report that a good start was made in 1946 repairing their telephone communications, 90 per cent. of which were destroyed during the war. During the year over 20,000 miles of telephone lines were reconstructed and 3,000 miles of new routes built. Some 1,300 exchanges were brought into operation and over 55,000 new subscribers given service.

In addition a start was made during the first quarter of 1947 with the manufacture of telephone apparatus and it is expected that the industry will quickly get into its stride.

Electrical Units

The National Physical Laboratory announces that the system of electrical units in use in its laboratories will, from the 1st January, 1948, be brought into line with the "absolute" units derived from the centimetre, gramme and second, which differ slightly from the mean values of the international units as realised at the various national laboratories as follows:

One international
- ohm = 1·00049 "absolute" ohms.
- volt = 1·00034 "absolute" volts.
- ampere = 0·99984 "absolute" ampere.
- watt = 1·00019 "absolute" watts.
- henry = 1·00049 "absolute" henries.
- farad = 0·99951 "absolute" farad

Similarly, from 1st January, 1948, the National Physical Laboratory will express all photometric values in terms of units based on the "new candle," in place of the international candle hitherto used. This unit of luminous intensity is such that the brightness of a full (or cavity) radiator (black body) at a temperature of solidification of platinum is 60 new candles per square centimetre. The "new lumen" is the luminous flux radiated within unit solid angle by a uniform source having an intensity of one new candle.

The Post Office will, in due course, fall into line with the National Physical Laboratory and adopt the new units for precise measurements.

Retirement of A. Speight, I.S.O., M.I.E.E.

Mr. Speight retired on June 30th, 1947, after 47 years in the telephone engineering business. The last 34½ years were in service with the Post Office which he joined in 1913 from the National Telephone Company.

A native of Yorkshire, he started his career as an apprentice with the National Telephone Company at Bradford in 1904. In 1909, at the age of 21, he resigned and took a trip to Canada and the United States, where he was employed by the Bell Telephone Company. On returning to this country after nine months' absence, he re-joined the National Telephone Company at Bradford and in 1910 became District Electrician, East Yorkshire District. In 1911 he was promoted and came to the Company's Headquarters in London. After the transfer of the N.T.C. to the Post Office, he entered the Engineer-in-Chief's Office of the Post Office in 1913 as a junior Engineer, becoming an Assistant Engineer (Old Style) in 1914. After serving in the Royal Engineers and obtaining the rank of Acting Captain he returned after the war to the Telephone Branch of the Engineer-in-Chief's Office, where he had much to do with the introduction of rural automatic exchanges and became an authority on maintenance and procedure.

Mr. Speight made a second visit to the United States in 1933, this time as a member of a G.P.O. Commission.

In 1934, having obtained the rank of Assistant Staff Engineer, he was transferred to the Organisation and Efficiency Branch and took charge of that Branch in 1936 on promotion to Staff Engineer. He remained there until the outbreak of war in September 1939, when, as Chief Regional Engineer, he became one of the small band that started the Midland Region. From October 1st, 1944, as well as being Chief Regional Engineer, he acted as Deputy to the Regional Director. His previous experience in maintenance and organisation was tested during the formation of the Region and the maintenance of the telecommunications services under war conditions. He emerged with flying colours. There is no doubt that his knowledge and experience have left their mark on the organisation and maintenance procedure in the Post Office.

Mr. Speight's outstanding characteristics were his thirst for details and his patience in investigating any problem ; his capacity for hard work was outstanding. He has left many friends in the Post Office, both among his colleagues and those who were privileged to serve under him, and all will wish him the very best during his retirement.

J. S.

Retirement of R. M. Chamney, B.Sc., A.M.Inst.C.E., A.M.I.E.E.

Mr. Chamney retired on July 25th, 1947, after just over 35 years with the British Post Office. Before entering the Post Office he was in the service of the National Telephone Company, chiefly engaged on research work in connection with local lines and transmission.

His early service with the Post Office was in the Research Section, where he worked with the late Mr. C. Robinson, chiefly on the early form of telephonic repeaters. The early work on repeaters proved invaluable during the 1914-18 war when Mr. Chamney was engaged in the development, manufacture and maintenance of repeaters to augment the main lines of communication. All the apparatus required was designed and produced in the Research Section. After the war the development of repeatered circuits, both 4- and 2-wire, continued. One of the many devices that were developed was the echo suppressor which Mr. Chamney and Mr. Robinson patented and the invention was used all over Europe.

In 1927 Mr. Chamney left the Research Section and was transferred to the Telephone Branch under Mr. A. B. Hart. It was here that Mr. Chamney made his first contacts with the international side of the work. He took charge of international lines section and has seen the international service grow from almost nothing to its present large and intricate network.

In 1932 he was promoted to Executive Engineer and took over inland transmission and rose to the rank of Staff Engineer in charge of the Lines Branch on March 1st, 1937. During his time in the branch he has been directly connected with the provision of "zero" 4-wire backbone trunks, the design and development of the inland trunk system, and the introduction of multi-channel carrier and co-axial systems.

He is one of the fast dwindling band who have seen the development of long distance transmission through all its phases, from overhead bare wires, to the present high frequency technique. His well-known cheery manner, energy and enthusiasm will be missed from the Department.

He is almost as well known to telephone engineers all over the world as he is to those in this country. He has been associated with the growth of the C.C.I. (Comitė Consultatif International Telephonique) from the beginning and on the resumption after the war became President of the third C.R., an honour which he well deserved.

J.S.

H. Williams, A.C.G.I., M.I.E.E.

In taking up the appointment as Staff Engineer in the Transmission and Lines Branch Mr. H. Williams follows a succession of men well known in the telephone art, both at home and abroad—Messrs. Hill, Hart, Hines, and Chamney. Mr. Williams studied electrical engineering in one of H.M. Dockyards and then at London University (City and Guilds Engineering College).

He entered the P.O. Engineering Dept. as a Probationary Assistant Engineer in January 1926 and spent the next twelve years in the Research Branch, being promoted there to Executive Engineer. His work was mainly in connection with signalling problems and embraced contacts, relays, and D.C. dialling developments.

In September 1938 he was transferred to "Lines" Branch as an Assistant Staff Engineer and shared in the development of the modern audio, carrier and coaxial transmission systems as well as the many and exacting tasks which fell to the Branch during the war. His combination of first-hand knowledge and experience in both signalling and transmission will be of greatest value in this period in which the economic method of trunk circuit provision and operating is becoming more and more technically complicated. Mr. Williams serves on the 3rd C.R. of the C.C.I.F. and in this work and in connection with the engineering problems of international telephony will ably represent his country in the international field. He carries with him the best wishes of his many friends for his success in his new appointment.

A. J. J.

L. L. Tolley, B.Sc.(Eng.), M.I.E.E.

Mr. Tolley, who succeeds Mr. Speight as Chief Regional Engineer, Midland Region, received his early training at University College, Southampton, obtaining a London University degree in 1922. After a further 12 months' study and a few months with the British Thomson Houston Co., he entered the Post Office Engineering Department as a Probationary Assistant Engineer in March, 1924, and was posted to the Research Station at Dollis Hill.

At first Mr. Tolley was employed largely in metallurgical work in the Materials and Measurements Group and, in 1932, took charge of the workshop and drawing office. Shortly afterwards, on promotion to Executive Engineer, he added the station services to his responsibilities. During the period Mr. Tolley was in charge of the workshops, he had to undertake many varied and interesting jobs, one of which was the construction of TIM.

In 1938 Mr. Tolley left Dollis Hill to take up an appointment as Assistant Superintending Engineer, Eastern District, becoming Regional Engineer in charge of maintenance and training when the Home Counties Region was set up in 1939. The war years proved strenuous ones and Mr. Tolley carried his full share of the load as well as being P.O. liaison officer to the Regional Commissioner and Commander of a P.O. Home Guard battalion, and later Regional H.G. Commander.

Early in 1944 Mr. Tolley was appointed Deputy Chief Regional Engineer in the Home Counties Region, retaining the duty connected with maintenance and training, and he remained on this work until his present appointment.

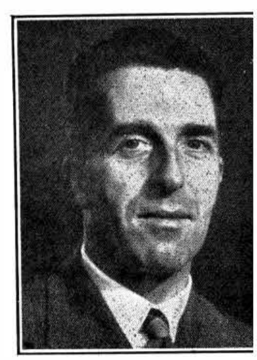
Mr. Tolley is taking up his new post at a most difficult period, but his ability and experience coupled with a kind and understanding manner will ensure his success in his new sphere of activity.

W. E. H.

R. J. Halsey, B.Sc., A.C.G.I., D.I.C., M.I.E.E.

Reginald John Halsey was born in Portsmouth and received his early education there obtaining a Roya Scholarship to the City and Guilds College in 1923 Having obtained his A.C.G.I. in 1925, Mr. Halsey chose traction for his Post-Graduate Course and in 192(received his D.I.C., and B.Sc. (Eng.) with first-class honours. After passing another year at the Guilds as a demonstrator he entered the Post Office in January 1927 as a Probationary Assistant Engineer and joined the staff of the Research Branch at the laboratories in Marshalsea Road, where main line transmissio problems were studied. Mr. Halsey was engaged particularly on carrier transmission, which was in it infancy at the beginning of this period. This sectio was transferred to Dollis Hill in 1933. Many carrie systems of the types he developed are still in use and one type formed the basis of a system put into considerable use by the Army in the late war.

In January 1936 Mr. Halsey was promoted t Executive Engineer to take charge of this section This was followed in March 1941 by promotion to A.S.E., also in the Research Branch, and to Staff Engineer in August 1947.



During his career in the Post Office Mr. Halsey has dealt with nearly all aspects of telephone transmission. He has served on many committees and conferences, both national and international, dealing with telecommunications, and has contributed papers to the I.E.E., I.P.O.E.E., and many articles to this Journa One subject in which Mr. Halsey has been particularl concerned in latter years is the development (

specialised equipment for submarine cables, including submerged repeaters, and such equipment is in use on many of our long submarine cables.

As a Staff Engineer in the Research Branch Mr. Halsey will now control the activities of a number of groups mainly on Transmission work. His many friends and colleagues will wish him success safe in the knowledge that his technical ability, good humour and co-operative spirit will ensure it.

H. W.

New Managing Editor

Mr. H. Leigh, consequent upon his promotion to Regional Engineer, Home Counties Region, has relinquished the post of Managing Editor of this Journal. He is succeeded by Mr. G. E. Styles who, since 1940, has been Assistant Editor. Mr. F. Warren will replace Mr. Styles as Assistant Editor. The Board regrets that Mr. Leigh's official duties will not permit of his continuing in the post of Managing Editor and wishes to place on record its appreciation of the excellent service he has rendered.

Institution's Library

Recent additions to the Library include the following:

1749 *Introduction to Atomic Physics.* Semat (American 1946).

A short introductory chapter reviews those fundamental concepts of electricity and magnetism essential to the study of atomic physics; the second chapter introduces the atom and presents the experimental evidence leading up to Rutherford's nuclear theory of the structure of the atom, the properties of the electron are developed, methods of measuring atomic masses with the mass spectrograph discussed and the subject of radioactivity introduced in such a manner that it leads directly to Rutherford's nuclear theory based on the experiments on the scattering of alpha particles. In Chapter III the structure of the atom is further investigated through its interaction with electromagnetic radiation leading to the Zeeman effect, photoelectric effect and a study of X-rays and gamma-radiation. In further chapters the wave and particle concepts of both radiation and matter are developed and are applied to the extranuclear structure first to the case of hydrogen and then to the more complex atoms. Since both optical and X-ray spectra have contributed immensely to the knowledge of atomic structure, these topics are considered in some detail both from the point of view of the simpler vector model of the atom and from that of wave mechanics, but the treatment, although extensive, has been kept as simple as possible.

1750 *Calculating Machines.* Hartree (British 1947).

An inaugural lecture by the Plummer Professor of Mathematical Physics in the University of Cambridge on recent and prospective developments and their impact on Mathematical Physics.

1751 *Physical Constants.* Childs (British 1946).

A useful book of tables, the constants being given with the proper number of significant figures and most recent determinations.

1752 *Industrial Production Illustration — Pictorial Drawing.* Hoelscher, Springer and Pohle (American 1946).

Covers the entire range of pictorial drawing from both the theoretical and practical points of view. Both freehand and instrumental layouts are dealt with, and all procedures are carefully explained and illustrated by break-down sketches showing step-by-step construction. The making of axonometric drawings has been illustrated and discussed in the third quadrant rather than in the first quadrant. Material of three point perspective is included together with a chapter on available equipment and special methods for making pictorial drawings, and a list of visual aids—motion pictures and film strips—correlated with the material in the text.

1753 *Experimental Radio Engineering.* Rapson (British 1944).

This book sets out a number of experiments and methods of measurement, the majority of which may be carried out with standard laboratory equipment. The following fields are covered: series and parallel circuits; coupled circuits; static characteristics of electron tubes; dynamic constants of thermionic valves; characteristics of amplifiers and detectors; thermionic valves as oscillators; audio frequency and radio frequency measurements; characteristics of attenuators and filters: radio receiver tests; electro-acoustic tests; cathode ray tubes, time bases and applications.

1754 *Introduction to Atomic Physics.* Tolansky (British 1946).

A comprehensive survey of the more important experimental work leading to modern concepts of atomic structure; progressing from the discovery of the electron towards the end of the 19th century, to the present day methods of atomic bombardment with high speed neutrons. An appendix is included on atomic energy and nuclear fission.

1755 *Varnished Cloths for Electrical Insulation.* Chatfield and Wredden (British 1946).

An interesting and useful contribution to the general knowledge of raw materials and intermediates used as components of electrical assemblies.

1756 *Introduction to Microwaves.* Ramo (American 1945).

A non-mathematical discussion on concepts. Physical pictures and viewpoints are described that have been found useful both to those doing active work in this relatively new branch of engineering and to others who desire merely a better appreciation of it.

L. A. CARTER,
Librarian.

Regional Notes

Scottish Region

PREHISTORIC FIND

While Post Office contractors were digging a trench for cable between Abernethy and Newburgh a "short cist" or ancient tomb was found. These small burial chambers were built in the late Stone Age, probably 3,500 years ago, and are of the simplest form of construction. The one found consisted of large sandstone slabs placed vertically to form four sides and surmounted by a massive cover-stone.

The small internal measurements of the chamber, 3 feet long, 2 feet high and 15 inches wide are explained by the fact that the builders of this type of tomb buried the body in a crouched position.

The cist had been set in the natural gravel subsoil. The floor had been sanded and about the centre a small

FIG. 1.

food vessel (Fig. 1) lay on its side but there were no traces of the skeleton.

The urn is vase shaped, 4¼ inches high with a rim-diameter of 4½ inches and is supposed to have contained food for the journey to the next world. A moulded design appears on the outside of the vessel. It is in the National Museum of Antiquities of Scotland, Queen Street, Edinburgh.

Abernethy in Perthshire, near where the find was made has long been known to have been a dwelling place of the ancient peoples of this country and the Pictish tower in the village churchyard is one of only two to be found in Scotland.

Thanks are due to the Keeper of the National Museum of Antiquities for much of the above information and for permission to reproduce the photograph of the prehistoric vessel. J. B. D.

North-Eastern Region

LEEDS TRUNK EXCHANGE
2V.F. TANDEM SWITCHING CENTRE

An extension of signalling over the trunk network was inaugurated at Leeds in July 1947. Primarily as a relief to the Leeds trunk switchboard, the group centres Bradford, Halifax and York code dial to selectors in the trunk exchange and obtain their own calls direct to London, Birmingham, Liverpool, Glasgow, Nottingham and Newcastle.

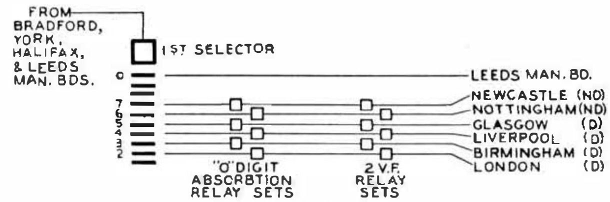


FIG. 1.

The scheme is shown in the trunking diagram (Fig. 1). The group centre operator has access to a group of junctions terminating on 200-outlet first selectors at the Leeds trunk exchange, the outlets of which are associated with routes to zone centres. The 2V.F. signalling equipment requires an appreciable period after seizure before it is ready to receive impulses; to meet this need operators at the group centres are instructed to dial '0' as a second digit, the latter being absorbed by the digit absorbing device connected between the selector level and the outgoing 2V.F. relay set, which is seized at the outset. This renders it unnecessary for the operator to provide a delay by pausing between dialling.

For normal junction routine tests from the group centres '0' is dialled, which routes to the Leeds manual board.

The scheme is working satisfactorily; later, other group centres will be given access to the tandem switching so quickening up the trunk service by the elimination of another "operator stage."

South-Western Region

On the 31st May, B.E.A. pilots returning from Jersey to Guernsey reported that two "balls of fire" had struck Jersey in the St. Ouen district, and coincident with this report the London-Jersey and Guernsey-Jersey carrier systems ceased to operate. The set-up of these systems is as follows :—

London-Jersey

Is worked Duplex, i.e. only one cable is employed for both directions of transmission, which occupy different parts of the frequency spectrum, 12-60 kc/s on the "go" and 72-120 kc/s on the "return." Coaxial submarine cable is used for the sea portions, and balanced-pair cable for the land portion of the system; matching transformers designed by the Research Branch are used to match the submarine cable to the balanced pair cable, and the carrier terminal to the balanced pair cables.

Guernsey-Jersey

An army system (Apparatus Carrier Telephone 1 + MK II) is in use on the Guernsey-Jersey system; the set-up being similar to the London-Jersey system except that the "go" employs a frequency band 4 kc/s to 16 kc/s and the "return" 19 kc/s to 32 kc/s.

Investigation disclosed that the matching transformer on the London-Jersey system at the repeater station St. Helier, and at the cable hut Plemont, were damaged, the winding ends being found disconnected at the point where they enter the coil cheek. The Guernsey-Jersey system matching transformer at Plemont was damaged similarly, but the transformer at the repeater station (a different type, of the 143 pattern) was not damaged.

The damaged transformers were replaced, and both systems restored to service, and apparently worked perfectly except that the music circuit which occupie the frequency band up to approx. 10 kc/s on the London-Jersey system was found to be faulty. This music circuit is separated from the carrier system proper by means of line filters located at the cable hut Plemont, and continues from Plemont to St. Helier on a pair in a 14 pr. 40-lb. cable in the same duct as the two balanced pair cables. This pair was found to be earthing and a measurement placed the fault at a joint in an avenue of elm trees near St. Ouens Manor. The track was opened at the foot of an elm tree, and about 2 ft. distant from it, where it was discovered that the asbestos cement duct was shattered for a distance of about 10 ft. All three cables are protected and the tape wrappings round the joints of the balanced pair cables were burnt and the lead sheath punctured. At a point about 18 in. from the joint a piece of the asbestos cement duct had perforated one of the balanced pair cable sheaths and was firmly wedged in the fracture. Exactly opposite this perforation, it was possible to push a rod through a hole in the ground extending from the asbestos cement duct to a point at the base, and to one side of the tree. A similar hole was found at a point equidistant from the tree but on the other side of it. Immediately above each hole the bark of the tree was scarred as though struck by a missile, whilst the grass around the holes was burnt. Subsequent tests disclosed faults on other pairs and at other points on the 14 pr. 40 cable, but the balanced pair cables have not to date disclosed any other faults. It is not clear how the holes in the ground were made, or indeed whether the " missiles " came down, or went up, but it is an undeniable fact that no trace of the " missiles" has ever been found.

Junior Section Notes

Edinburgh Centre

The Annual General Meeting was held on the 27th June, 1947. After an account of the financial statement, the election of office bearers took place :—

Chairman : Mr. J. G. Kelly.
Vice-Chairman : Mr. R. A. Notman.
Secretary & Treasurer : Mr. I. W. L. Hendry.
Librarian : Mr. J. M. Riva.
Comr ittee : Messrs. W. P. Davidson, J. M. Wright, W. F. Irvine, W. E. Galloway and K. S. Grainger.
Auditors : Mr. G. J. Ford and Mr. G. Anderson.

The committee are arranging for a wide range of lectures and visits during the coming session and it is hoped that they will be well supported; further details later.

I. W. L. H.

Taunton Centre

The Taunton Centre has now been revived, having been in a dormant state during the war.

Early in the 1946/7 session, visits were made to the Memorial Carillon at St. Mary's Church, Taunton, and to the B.B.C. transmitter at Washford Cross.

The assistant R.M.T.O. gave a talk on the construction and maintenance of the Morris Minor van. It was illustrated by a part-sectioned full-size model engine. Mr. A. S. Thomas, D.Sc., later read a paper on " The Co-axial Line." Papers have been read by our own members on such subjects as " The U.A.X.14," " G.P.O. Equipment in Radar," " Radio in Tanks," and " The Art of Study."

Perhaps the highlight of the session was the visit to Salisbury for a " Brains Trust " versus the Salisbury Centre, on December 18th. We were beaten 23-24, but we hope to avenge this defeat in the next session. We shall be pleased to hear from any other centres that may wish to issue a challenge to our team of eminent brains.

F. J. S.

Stoke-on-Trent Centre

Following the first post war General Meeting of 17th January, 1947, the Committee arranged two lectures to complete the session, the first on " Radio Direction Finding " by a fellow member, Mr. J. O. Jones, and the second on " Electricity in the Medical Profession," by Dr. J. J. Fry. The lectures were very informative and interesting and were well received by the large number of members present.

The membership is still increasing and now numbers 80. The local library is steadily being built up, and, together with the Senior Section library, is being fully utilised by the members.

The following provisional programme has been arranged for the forthcoming Session 1947-48.

Lectures

" Cabinet and Pillar Distribution," by Mr. F. Potts.

" Modern Developments in Auto Telephony," by a member of the Engineer-in-Chief's Training School, Stone.

" Ceramic Insulator Production and Testing," by a member of the technical staff of Messrs. Taylor, Tunnicliffe. (Including a 16 mm demonstration film).

A further lecture by Dr. J. J. Fry.

" Production of Copper Wires," by a member of the Research Dept. of Messrs. Thomas Bolton & Sons.

" The Diesel Engine," by Mr. J. Hollins.

Visits

The Engineer-in-Chief's Training School, Stone.

Messrs. Taylor, Tunnicliffe & Co., Insulator Manufacturers.

Messrs. Robert Hydes Steel Foundry.

" The Evening Sentinel " Newspaper.

The Stoke-on-Trent City Gas Works.

Messrs. Thomas Bolton & Sons, Copper Wire Manufacturers.

The co-operation and goodwill extended by the above individuals and industrial concerns is much appreciated, and we look forward with great interest to a successful session.

A. P.

Staff Changes

Promotions

Name	Region	Date
Dep. C.R.E. to C.R.E.		
Tolley, L. L. ..	H.C.Reg. to Mid.Reg.	1.7.47
Asst. Staff Eng. to Staff Eng.		
Williams, H. ..	E.-in-C.O.	26.7.47
Halsey, R. J. ..	E.-in-C.O.	15.8.47
Asst. Staff Eng. to Dep. C.R.E.		
Smith, H. S. ..	E.-in-C.O.to H.C.Reg.	1.7.47
Asst. Staff Eng. to Dep. Contr.		
Hibberd, W. A. ..	Factories Dept. ..	10.6.47
Exec. Engr. to Asst. Staff Engr.		
Tobin, W. J. E. ..	L.T.R. to E.-in-C.O.	2.7.47
Diack, W. H. ..	N.W. Reg.	1.7.47
Pearson, A. W. C. ..	E.-in-C.O.	26.7.47
Boocock, R. O. ..	H.C. Reg.	1.7.47
Leigh, H. ..	E.-in-C.O.to H.C.Reg.	1.7.47
Area Engr. to Prin.		
Harrison, G. B. W. ..	L.T.R. to Telecomms Department. ..	1.8.47
Area Engr. to Asst. T.M.		
Williams, E. H. ..	Mid. Reg.	24.4.47
Engr. to Exec. Engr.		
Piggott, J. ..	E.-in-C.O.	1.7.47
Robertson, C. D. S. G.	L.T.R.to H.C.Reg. ..	1.7.47
Owen, W. ..	N.W. Reg.	1.7.47
Britton, G. A. C. R.	E.-in-C.O.	25.6.47
Hobbs, H. ..	S.W.Reg.to Mid.Reg.	29.6.47
Griffiths, G. J. ..	Mid. Reg.	1.7.47
Cox, R. H. ..	E.-in-C.O.	1.7.47
Arman, L. T. ..	L.T.R. to E.-in-C.O.	20.8.47
Engr. to S.S.O.		
Hansford, R. N. ..	E.-in-C.O.	11.8.47
Tech. to Asst. Engr.		
Heath, F. J. ..	S.W.Reg.to E.-in-C.O.	10.8.47
MacMahon, P. J. ..	L.T.R. to E.-in-C.O.	13.7.47
Hambrook, L. G. ..	N.E.Reg.to E.-in-C.O.	13.7.47
Jalland, K. F. ..	Mid.Reg.to E.-in-C.O.	13.7.47
Reddyhoff, G. ..	E.-in-C.O.	13.7.47
Loomes, E. A. ..	L.T.R. to E.-in-C.O.	13.7.47
Makemson, A. A. ..	L.T.R. to E.-in-C.O.	13.7.47
Ellis, D. R. B. ..	Mid.Reg.to E.-in-C.O.	13.7.47
Watkins, S. B. ..	N.E.Reg.to E.-in-C.O.	13.7.47
Jeynes, E. ..	E.-in-C.O.	13.7.47
Pate, H. R. ..	L.T.R. to E.-in-C.O.	13.7.47
Brierley, N. ..	N.W.Reg.to E.-in-C.O.	13.7.47
Davies, A. O. ..	N.W.Reg.to E.-in-C.O.	13.7.47
Billinghurst, F. M. ..	E.-in-C.O.	13.7.47
Hill, J. D. ..	N.E.Reg.to E.-in-C.O.	13.7.47
Stoate, K. W. ..	S.W.Reg.to E.-in-C.O.	13.7.47
Hurford, S. P. ..	E.-in-C.O.	13.7.47
Granger, S. H. ..	Mid.Reg.to E.-in-C.O.	13.7.47
Tungate, R. G. ..	Mid.Reg.to E.-in-C.O.	27.7.47
Turner, P. A. ..	L.T.R. to E.-in-C.O.	13.7.47
Scholey, D. H. A. ..	N.W.Reg.to E.-in-C.O.	13.7.47
Spencer, D. C. ..	E.-in-C.O.	13.7.47
Moore, J. C. ..	E.-in-C.O.	13.7.47
Searle, P. R. ..	E.-in-C.O.	13.7.47
Pattemore, T. E. ..	S.W.Reg.to E.-in-C.O.	13.7.47
Brooker, H. J. ..	S.W.Reg.to E.-in-C.O.	13.7.47
Sandeman, W. P. ..	Scot.Reg.to E.-in-C.O.	13.7.47

Name	Region	Date
Tech. to Asst. Engr.—continued		
Langton, H. J. ..	N.E.Reg.to E.-in-C.O.	13.7.47
Fidler, R. G. ..	L.T.R. to E.-in-C.O.	13.7.47
Drake, C. P. ..	E.-in-C.O.	13.7.47
Jones, S. I. ..	Mid.Reg.to E.-in-C.O.	27.7.47
Gough, G. J. ..	Mid.Reg.to E.-in-C.O.	13.7.47
Bagwell, V. E. ..	S.W.Reg.to E.-in-C.O.	13.7.47
Rawsthorne, A. L. ..	N.W.Reg.to E.-in-C.O.	13.7.47
Broadbent, F. ..	N.E.Reg.to E.-in-C.O.	13.7.47
Burrells, W. ..	E.-in-C.O.	13.7.47
Redburn, L. A. ..	S.W.Reg.to E.-in-C.O.	13.7.47
Jack, I. M. ..	E.-in-C.O.	13.7.47
S.W.IIA to Asst. Engr.		
Burdge, W. E. ..	S.W.Reg.to E.-in-C.O.	13,7,47
D'man Cl.II to Asst. Engr.		
Reeve, C. W. ..	H.C.Reg.to E.-in-C.O.	13.7.47
Asst.R.M.T.O. to R.M.T.O.		
Hunt, E. T. ..	S.W. Reg. to W. & B.C. Reg.	6.8.47
Coventon, A. E. ..	H.C. Reg.	20.8.47
M.T.O. I to Prin.		
Wood, E. W. ..	E.-in-C.O. to Postal Services Dept. ..	6.7.47
M.T.O. II to M.T.O. I.		
Marks, R. ..	E.-in-C.O.	1.8.47
M.T.O. III to M.T.O. II.		
Gibson, J. ..	E.-in-C.O.	12.7.47
Tech. Asst. to M.T.O. III.		
Cadge, E. R. ..	E.-in-C.O.	23.6.47
Mech. i/c I to Tech. Asst.		
Bailey, C. S. ..	E.-in-C.O.	1.7.47
Second Offr. to Chief Offr.		
Nairne, J. U. D. ..	H.M.T.S. *Alert* ..	30.11.45
Third Offr. to Second Offr.		
Lowe, J. M. S. ..	H.M.T.S. *Monarch* ..	14.3.46
McLagan, G. ..	H.M.T.S. *Alert* ..	7.10.46
Gillespie, A. B. ..	H.M.T.S. *Iris* ..	8.5.46
Fourth Offr. (T) to Third Offr. (T).		
Pointon, E. F. P. ..	H.M.T.S. *Ariel* ..	14.3.46
Chisholm, D. P. F. ..	H.M.T.S. *Alert* ..	7.5.47
McAuliff, E. R. ..	H.M.T.S. *Iris* ..	7.5.47
Field, A. N. ..	H.M.T.S. *Monarch* ..	7.5.47
Second Engr. to Chief Engr.		
Parker, C. ..	H.M.T.S. *Ariel* to H.M.T.S. *Iris* ..	25.2.45
Third Engr. to Second Engr.		
Millar, D. E. ..	H.M.T.S. *Iris* to H.M.T.S. *Alert* ..	23.6.45
Fourth Engr. to Third Engr.		
Brown, W. ..	H.M.T.S. *Alert* ..	4.8.45
Andrew, J. A. ..	H.M.T.S. *Iris* to H.M.T.S. *Monarch*	12.2.46
Lindsay, J. ..	H.M.T.S. *Iris* ..	14.3.46
Fifth Engr. to Fourth Engr.		
Maisey, S. ..	H.M.T.S. *Monarch* to H.M.T.S. *Alert* ..	19.12.46
Ramsay, G. C. ..	H.M.T.S. *Ariel* ..	14.3.46
Stronach, W. G. ..	H.M.T.S. *Ariel* to H.M.T.S. *Monarch*	19.7.46

Transfers

Name	Region	Date
Exec. Engr.		
Lemmey, C. W.	L.T.R. to E.-in-C.O.	28.7.47
Engr.		
Connelly, A. E.	E,-in-C.O. to N.I.Reg.	28.8.47
Miller, R. W.	W. & B.C. Reg. to E.-in-C.O.	31.8.47
Gray, R. E.	E.-in-C.O.to H.C.Reg.	1.6.47
Lloyd, H. H.	E.-in-C.O.to Mid.Reg.	15.6.47
Prob. Engr.		
Gandon, N.	E.-in-C.O. to W. & B.C. Reg.	31.8.47
Chief Inspr.		
Green, E. S.	E.-in-C.O. toN.E.Reg.	1.6.47
Power, W. C. S.	E.-in-C.O.to H.C.Reg.	1.7.47
Thompson, S.	L.T.R. to E.-in-C.O.	5.8.47
Inspr.		
Campbell, K. W.	L.T.R. to E.-in-C.O.	1.7.47
Asst. Engr.		
Blann, R. E.	E.-in-C.O. to Min. of Tpt.	1.8.47
Cowling, H.	E.-in-C.O. to Min. of Tpt.	1.8.47
Wheldon, E. V.	E.-in-C.O.to Mid.Reg.	5.8.47

Name	Region	Date
Asst. Engr.—continued		
Farmer, W. H.	E.-in-C.O. to N.I.Reg.	6.8.47
Sephton, R. H.	N.W.Reg.to N.E.Reg.	11.8.47
Slater, T. A.	E.-in-C.O.to N.E.Reg.	17.8.47
Broadbent, F.	E.-in-C.O.to N.E.Reg.	17.8.47
Johnston, J. A.	E.-in-C.O.toN.E.Reg.	24.8.47
Bagwell, V. E.	E.-in-C.O.to S.W.Reg.	31.8.47
McLeod, J.	E.-in-C.O.to N.E.Reg.	1.9.47
M.T.O. II.		
Collman, E. L.	London to E.-in-C.O.	20.8.47
Daft, W. E.	H.C.Reg. to London	20.8.47
Chief Engr.		
Sloss, J.	H.M.T.S, *Monarch* to H.M.T.S. *Iris*	8.8.47
Thomson, A. J.	H.M.T.S. *Ariel to* H.M.S.T. *Monarch*	8.8.47
Parker, C.	H.M.T.S *Iris* to H.M.T.S. *Ariel*	1.9.47
Commander		
Betson, J. P. F.	H.M.TS *Alert* to H.M.T.S. *Monarch*	25.8.47
Wallis, R. H. J.	H.M.T.S, *Monarch* to H.M.T.S. *Alert*	25.8.47

Retirements

Name	Region	Date
Staff Engr.		
Speight, A.	Mid. Reg.	30.6.47
Chamney, R. M.	E.-in-C.O.	25.7.47
Regl. Engr.		
Jeary, L. G.	N.W. Reg.	30.6.47
Exec. Engr.		
Bolton, G. F.	W. & B. C. Reg.	31.5.47
McGowan, C. R.	E.-in-C.O.	30.6.47
Engr.		
Cortlandt-Simpson, J. W.	E.-in-C.O. (Res.)	31.12.46
Stott, S. A.	H.C. Reg.	31.3.47
Hughes, R. E. S. F.	E.-in-C.O.	31.5.47
Tetlow, F. E.	E.-in-C.O.	31.5.47
Hubbard, W. J.	L.T.R.	31.5.47
Bedford, J. G.	E.-in-C.O.	29.7.47
Buckland, F. H.	E.-in-C.O.	31.7.47
Chief Insp.		
Hopgood, C. L.	L.T.R.	5.5.47
Price, W. H.	N.W. Reg.	30.6.47

Name	Region	Date
Inspr.		
Hamblett, J.	N.W. Reg.	4.6.47
McClure, J.	N.I. Reg.	12.6.47
Smith, C. S.	Mid. Reg.	13.6.47
Lidington, L. H.	L.T.R.	26.6.47
Thomas, H.	N.W. Reg.	29,6,47
Webb, C. W.	N.W. Reg.	30.6.47
Edgar, A.	L.T.R.	30.6.47
Rooke, A. J.	L.T.R.	4.7.47
Levy, B. J.	N.I. Reg.	31.7.47
Faulkner, F. G.	L.T.R.	26.8.47
Castro, D. J.	E.-in-C.O. (Res.)	31.8.47
Fourth Engr. (T).		
McKenna, P. A.	H.M.T.S. *Alert* (Res.)	22.6.47
Ramsay, G. C.	H.M.T.S. *Ariel* (Res.)	31.8.47
Fifth Engr. (T).		
Taylor, J.	H.M.T.S. *Monarch* (Res.)	31.8.47

Deaths

Name	Region	Date
Engr.		
Glazier, A. W.	E.-in-C.O.	25.6.47
Hibberd, R. M.	Mid. Reg.	3.7.47
Asst. Engr.		
Robinson, P.	N.E. Reg.	16.6.47
Fifth Engr.		
Watson, R. V.	H.M.T.S. *Monarch*	1.7.47

Book Review

"Second Year Radio Technology." W. H. Date, B.Sc., A.M.I.E.E. 222 pp. 155 ill. Longmans, Green & Co. 7s. 6d.

Mr. W. H. Date in his capacity as a senior lecturer in engineering has realised the need for a textbook on elementary radio theory, and in his "Second Year Radio Technology," a small well-produced volume has used his wide teaching experience in an attempt to fill a gap in the literature. To a considerable extent he has succeeded, particularly in his treatment of the behaviour of thermionic valves. The basic principles of diodes, triodes and pentodes are clearly presented and some of their fundamental circuit applications are described and briefly analysed in a manner which should appeal to most students. The author introduces this major part of his book with chapters on the properties of capacitors, inductors and resonant circuits and with descriptions of some modern examples of these components. It is pleasing to see simple vectorial diagrams introduced as an alternative to the purely algebraical approach to circuit behaviour, although it is unfortunate that there are no references to other works in which interested students can pursue the use of vectors. The last three chapters deal very briefly with the principles of simpledirection finding, the superheterodyne receiver and R.F. component measurements respectively.

The fourth chapter entitled "The Principles of Radio Communication" is a curious miscellany which, in 15 pages, ranges over electromagnetic radiation, aerials, the crystal receiver and finally the ear-piece and moving coil speaker. With such a wide coverage this chapter is of doubtful value, and the book might have been improved if these pages had been devoted to an expansion of the section on R.F. measurements—a weak point in many radio students' training.

An elementary text book of permanent value must not only deal adequately with a carefully restricted section of its subject but must be capable of stimulating the serious reader into exploring more deeply into other writings of more specialist authors. Mr. Date has concentrated on mentioning the whole range of the second year syllabus of the City and Guilds radio course in this one small volume, and the practical aspects of the subject have suffered at the expense of the theoretical. Also, he may introduce a feeling of complacency rather than ambition into his students, as, in adhering rigidly to the upper limit of his syllabus, which does not include the calculus, he has resorted to over-simplification, and even to the quoting of formulæ without proof or reference as in the paragraph on sideband production: these tendencies may tend to obscure some of the interesting controversial aspects likely to fire a student's enthusiasm for proceeding further into such a complex science.

Nevertheless, the man who is intent upon passing the examination for the City and Guilds Radio Certificate, Grade I, will undoubtedly find much of the radio theory set out in this book in neat and palatable form, with adequate diagrams, and questions (with answers) on which to test his grasp of each chapter. C. F. F.

Communications

All Communications should be addressed to the Managing Editor, *P.O.E.E. Journal*, Engineer-in-Chief's Office, Alder House, Aldersgate Street, London, E.C.1. Telephone: HEAdquarters 1234. Remittances should be made payable to "*The P.O.E.E. Journal*" and should be crossed "& Co."

Binding Cases

Cases for binding are available, and may be obtained from the Local Agents for 2s. Subscribers can have their copies of Volumes bound, at a cost of 7s. 6d., by sending the complete set of parts to the Local Agents or to the *P.O.E.E. Journal*, Engineer-in-Chief's Office, Alder House, Aldersgate Street, London, E.C.1. Orders for binding for Vols. 1-19 should indicate whether the original binding case with black lettering, or the later pattern with gold, is required. Cases with gold lettering are the only type stocked from Vol. 20 onwards.

Back Numbers

The price of the Journal, which is published quarterly, is 1s. (1s. 3d. post free) per copy, or 5s. per annum post free. Back numbers can be supplied, subject to availability of stocks, at 1s. each (1s. 3d. post free). Orders for back numbers may be sent to the Local Agents or to the Publishers.

Advertisements

All communications relating to space reservations should be addressed to the Advertisement Editor *P.O.E.E. Journal*, Alder House, Aldersgate Street London, E.C.1. Communications regarding advertisement copy, proofs, etc., should be addressed to the Publishers, Messrs. Birch & Whittington (Prop. Dorling & Co [Epsom], Ltd.), 49 Upper High Street, Epsom, Surrey

v

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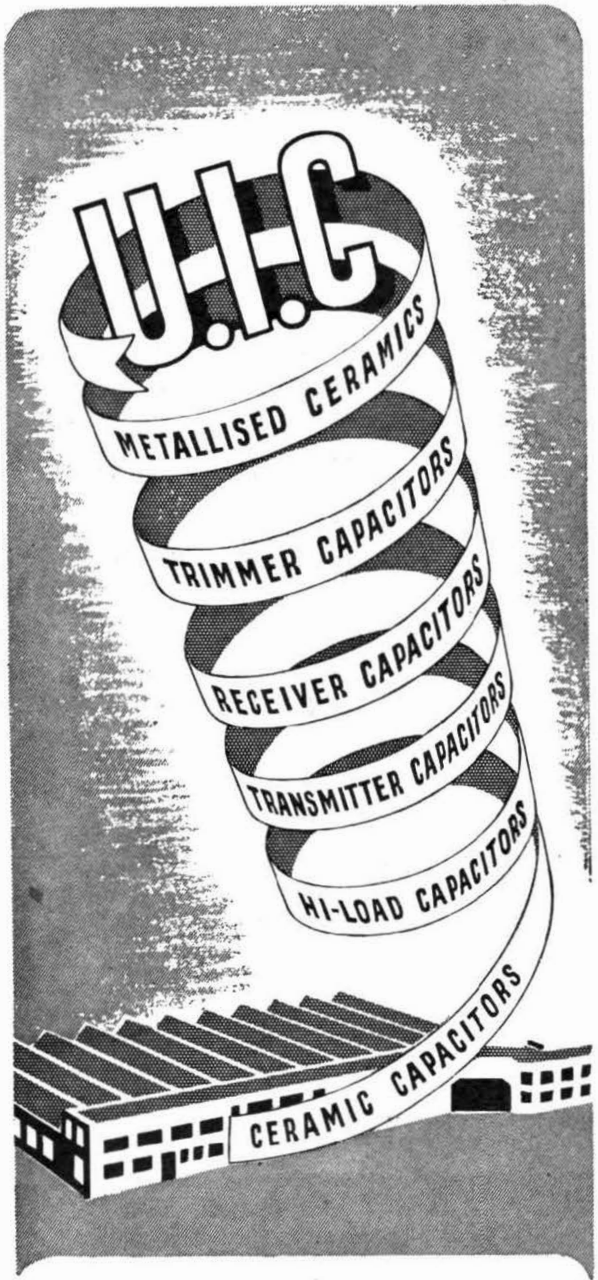
A16



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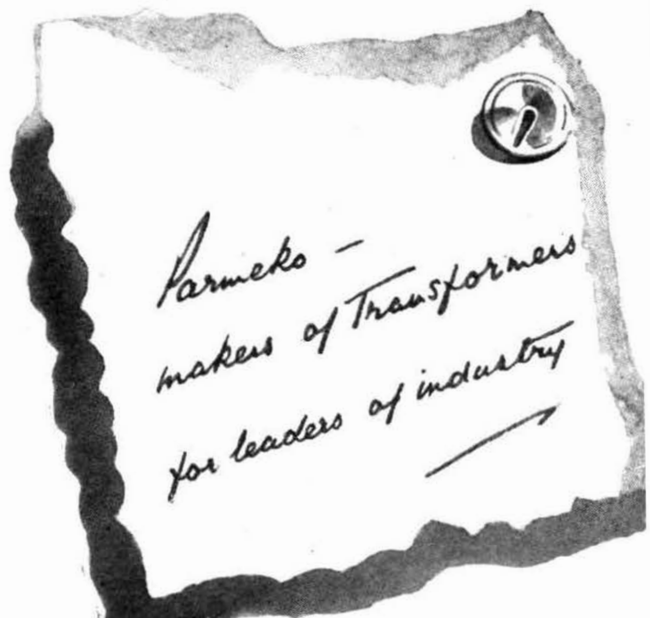

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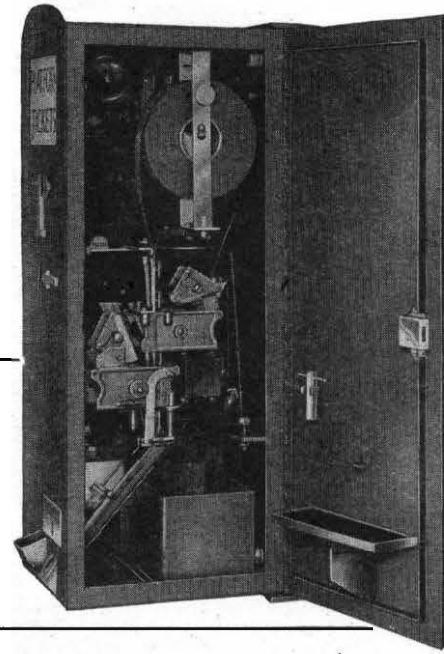

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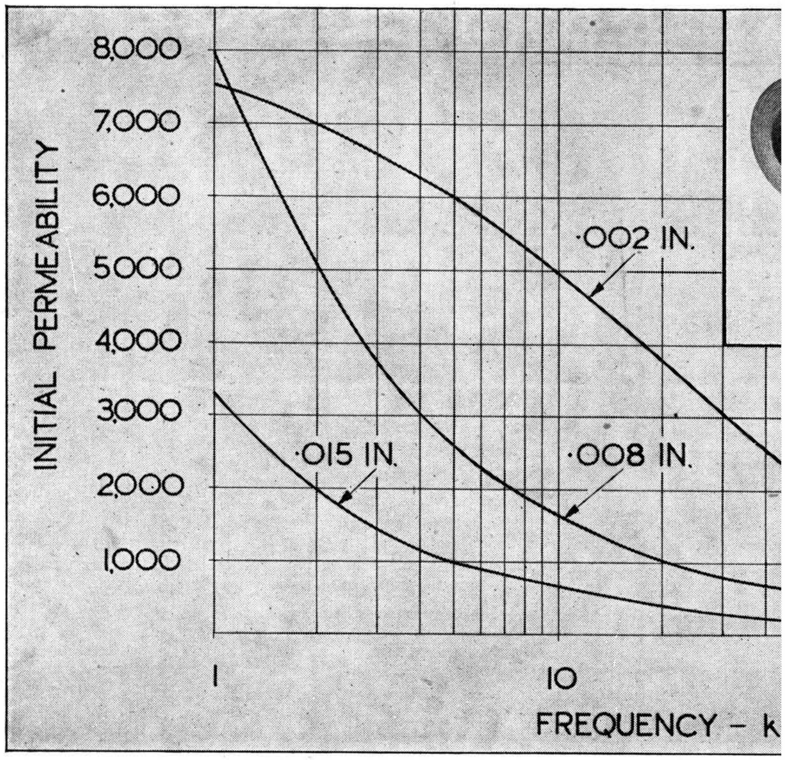

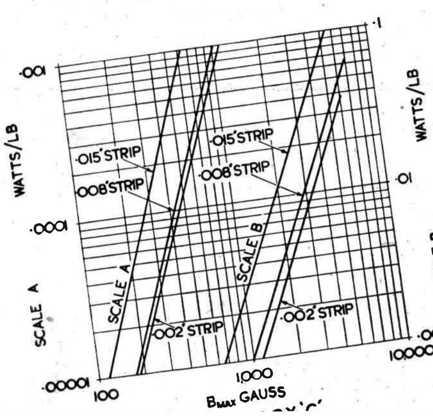

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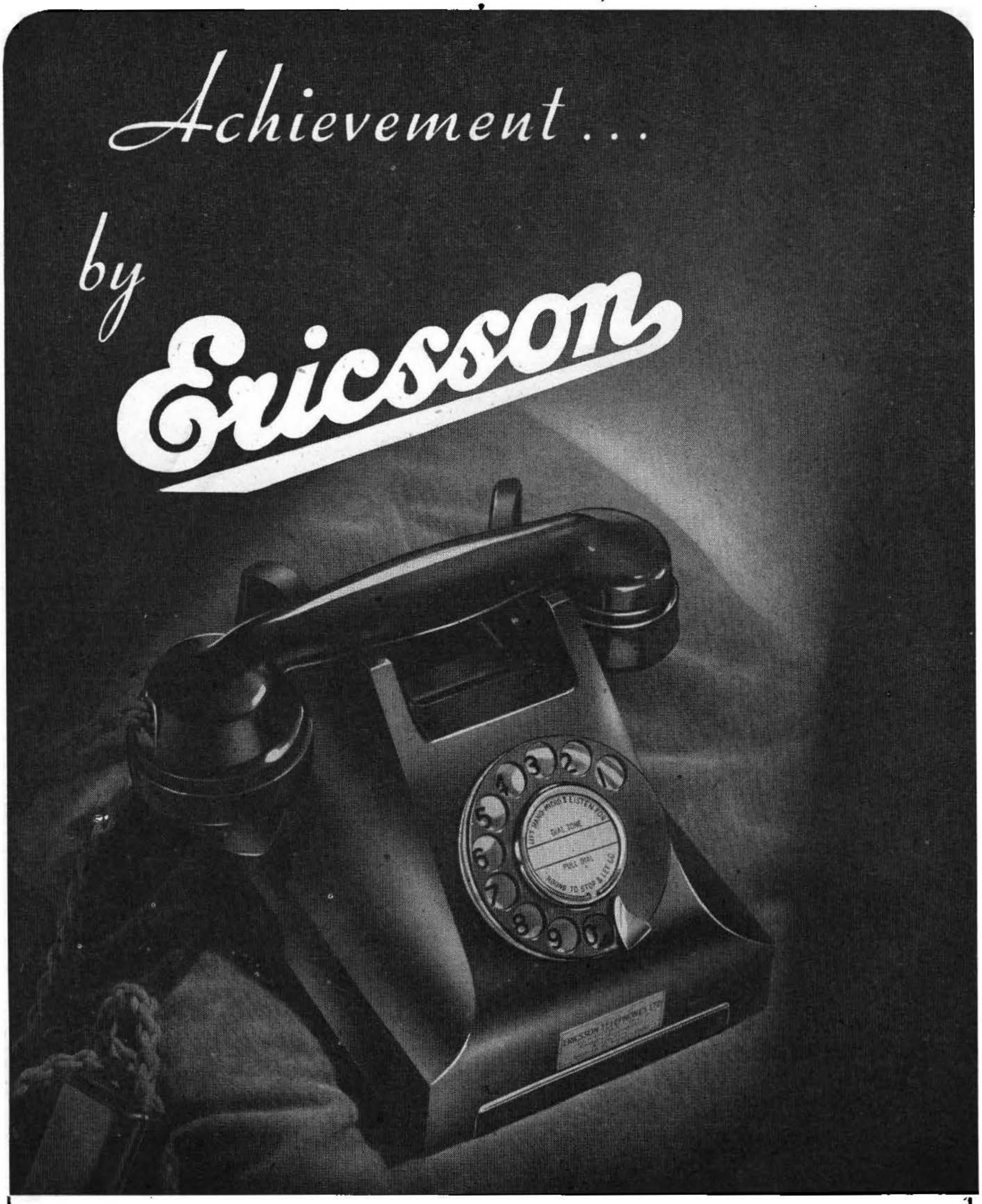
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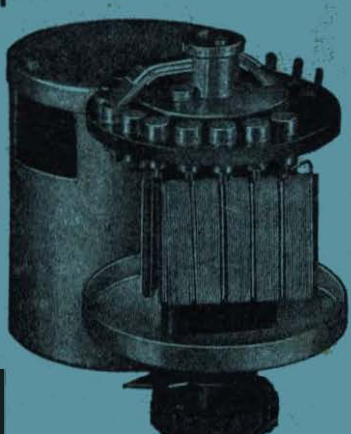

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CORRECTION

Fig. 11 on page 113 and Fig. 14 on page 114 should be interchanged.