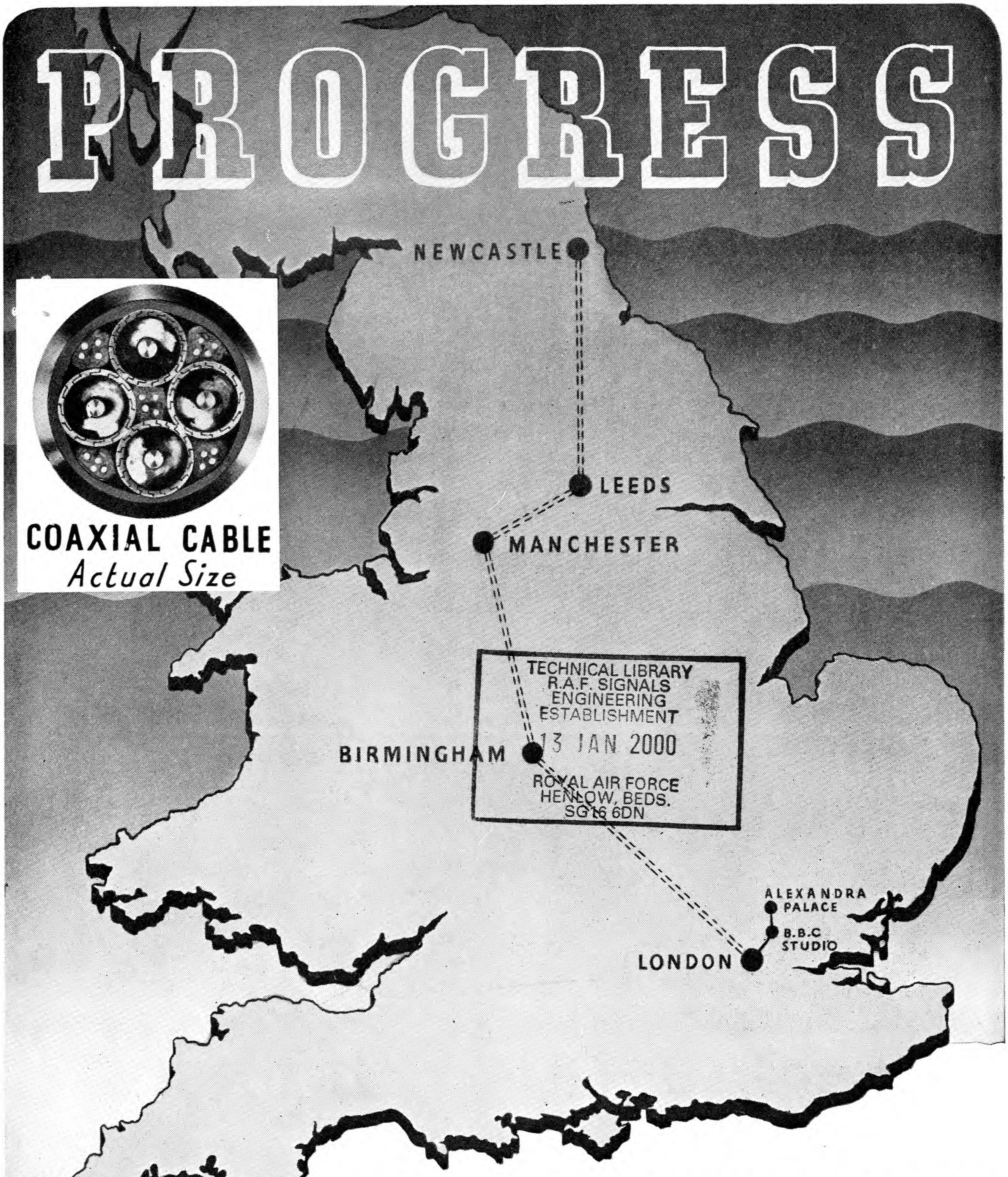
THE POST OFFICE ELECTRICAL ENGINEERS' JOURNAL

VOL. 30 **JULY, 1937** **PART 2**

CONTENTS

Price 1/- net

THE INSTITUTION OF POST OFFICE ELECTRICAL ENGINEERS



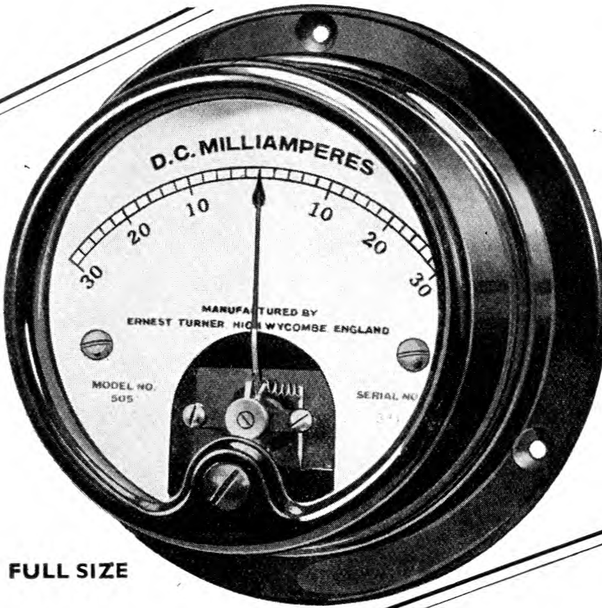
THE first installation of Coaxial Cable in Great Britain, now in progress between the towns marked on our map. This coaxial cable has been developed for multi-channel telephony and with a view to suitability for television transmission and is being manufactured and installed on behalf of the Post Office by

Standard Telephones and Cables Limited

NORTH WOOLWICH, LONDON, E.16 *Telephone: Albert Dock 1401.*

TURNER DIFFERENTIAL MILLIAMMETERS G.P.O. No. 17 & No. 18

Meet the most exacting demands for balancing currents in multiplex telegraph circuits. ———A quality product of outstanding merit———



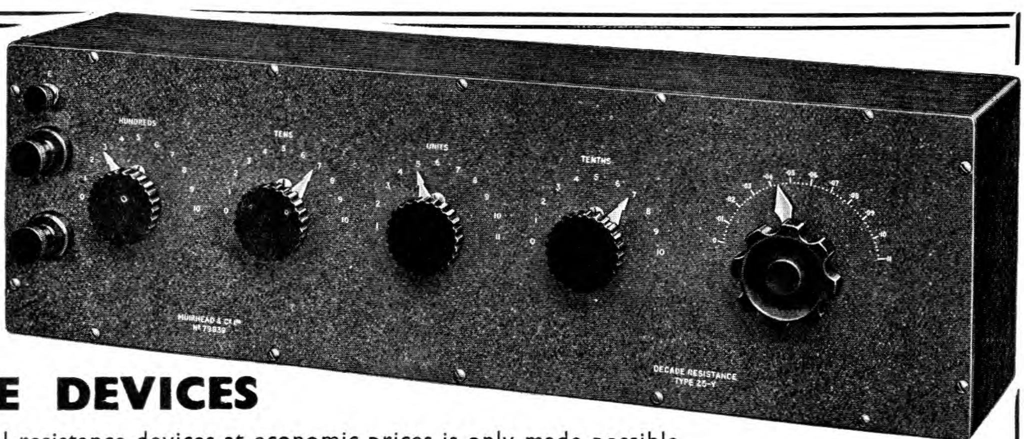
FULL SIZE

Also manufacturers of G.P.O. Detector No. 4, and a comprehensive line of instruments for precision electrical measurements.

ERNEST TURNER ELECTRICAL INSTRUMENTS, Ltd.

CHILTERN WORKS,
55-73 TOTTERIDGE AVENUE,
HIGH WYCOMBE,
BUCKS, ENGLAND

Telephone : High Wycombe 301.
Telegrams : Gorgeous, High Wycombe.



RESISTANCE DEVICES

The production of special resistance devices at economic prices is only made possible by the wide range of component switches which we have available. Some combination of these can usually be arranged to form the particular network and provide the degree of adjustment which you require.

The unit illustrated is a simple resistance box giving a range of 1.00 ohms to 1112.11 ohms in steps of 0.002 ohms.

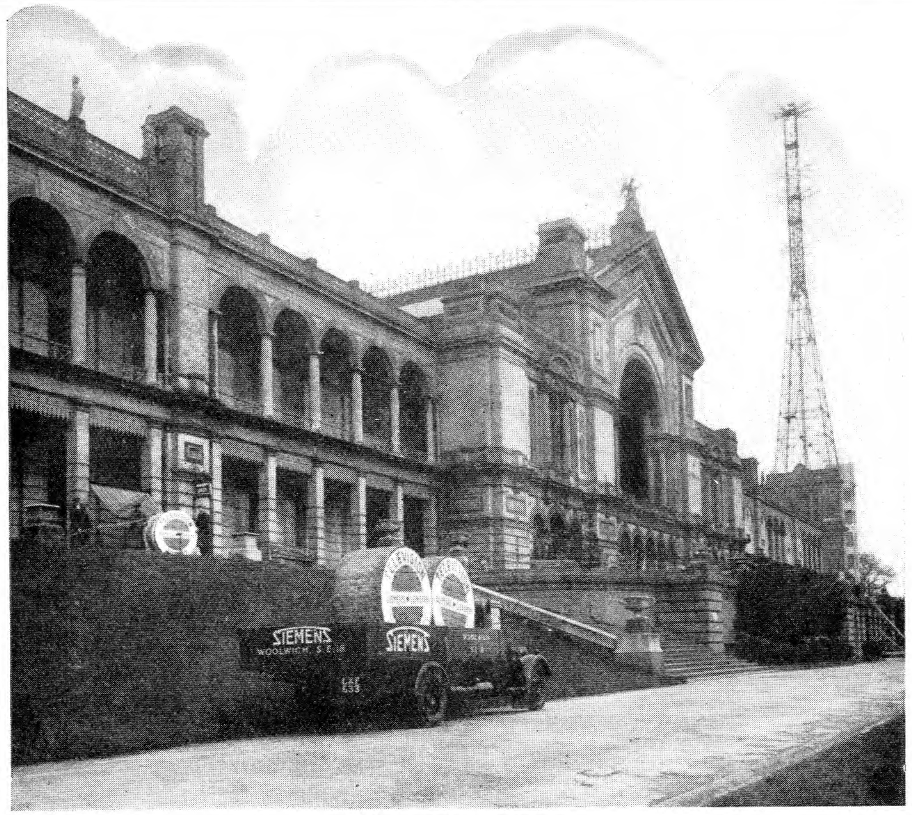
Standard Resistance Networks are described in Section 7 of our Catalogue, a copy of which will be supplied on request.

MUIRHEAD & CO. LTD.

MAKERS OF PRECISION INSTRUMENTS FOR OVER 50 YEARS

ELMERS END — KENT

TELEPHONE — BECKENHAM 0041-2

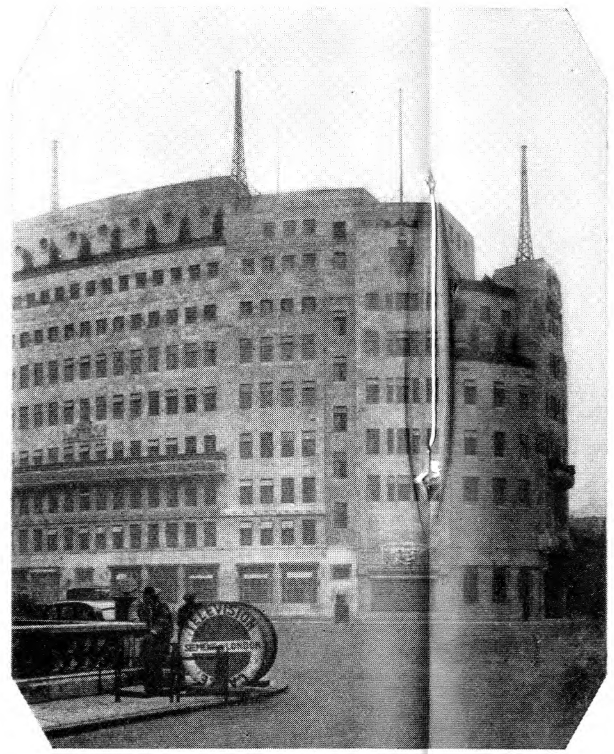


Alexandra Palace

Manufactured by
SIEMENS BROTHERS & CO., LTD.
under Patents of
ELECTRIC & MUSICAL INDUSTRIES LTD.
and laid to the order of the
BRITISH POST OFFICE


Houses of Parliament

THE NEW CABLE FOR TELEVISION

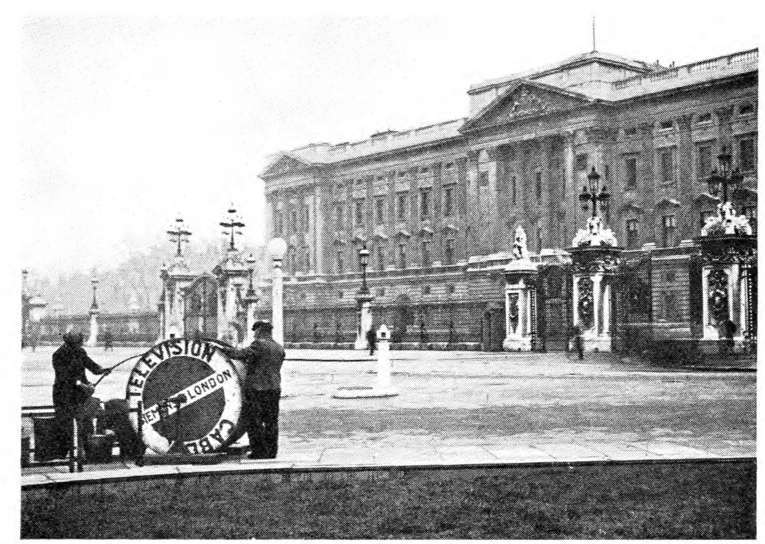

Broadcasting House

LENGTH 14½ MILES APPROX.

ALEXANDRA PALACE
BROADCASTING HOUSE
HOUSES OF PARLIAMENT — WESTMINSTER ABBEY — BUCKINGHAM PALACE — ST. JAMES'S PALACE — VICTORIA STATION

SIEMENS

SIEMENS BROTHERS & CO. LIMITED
WOOLWICH, LONDON, S.E.18
Telephone : Woolwich 2020



Buckingham Palace

4476 A
40μF
250 V. PEAK
WORKING
OF 0-5 M.F.D.
CAP. ·02 M.F.
I M.F.D
250 v. D.C. WORKING
0-5-·00014·0 μF
-6-·000245 μF
-7-·000272 μF
-8-·000290 μF
-9-·000323 μF
-10-·000430 μF
-11-·000780 μF
W36
0·1μF
4098 A
Standard
CONDENSERS
for
ALL REQUIREMENTS
OUR North Woolwich Factory is equipped with the most modern plant for production of Power, Telephone and Radio Condensers of the highest possible quality. If you are in the market for condensers we shall welcome the opportunity of quoting you upon receipt of your requirements.
Standard Telephones and Cables Limited
NORTH WOOLWICH, LONDON, E.16
Telephone - - - - Albert Dock 1401
BRANCHES & REPRESENTATIVES THROUGHOUT THE WORLD

THE POST OFFICE ELECTRICAL ENGINEERS' JOURNAL

Vol. XXX July, 1937 Part 2

Street Traffic Control centralised in the Telephone Exchanges in Amsterdam

Dr. Ir. C. E. A. MAITLAND
of the Dutch P.T.T. Engineering Dept.

The author describes the centralised traffic control system provided in Amsterdam. With this installation the time periods at intersections can either be automatically varied and intersections interlinked according to the traffic density, or the control can be carried out from police headquarters. The controlling apparatus consists of telephone type relays and switches and is housed in the telephone exchanges. The article concludes with an economic comparison between this and other systems and a summary of the advantages.

Introduction.

STREET traffic control should not be only the arbitrary allotment of the right-of-way on busy intersections ; it ought to be the regulation and the distribution of the traffic as a whole over the greater part of the city.

Automatic traffic control is not a mere rationalisation and saving of labour ; it is the best, if not the only, way to obtain a reasonable co-ordination of the traffic control on the consecutive intersections of the main thoroughfares in a vehicle-crowded city. Traffic control on a particular road-crossing affects the distribution of traffic in the main channels leading to and from that intersection.

Finally, the problem is not to avoid collisions by stopping the traffic, but to obtain a regular traffic flow. This enables the maximum capacity of the roads to be utilised at the highest degree of safety for the public.

For a rational distribution the intersections ought to be interlinked as far as they are interdependent, and as far as they influence each other. This mutual influence is a function of the traffic itself and is liable to change many times during the day. For this reason not only must the traffic regulation at the intersections be flexible, but a flexible interlinking of the intersections must also be provided.

The larger the area of interdependence, the more difficult becomes the problem of controlling the whole of the traffic regulation in this territory from one central point, since an extensive wire system between the intersections and a complicated master-switching mechanism somewhere on the road are required.

If the nearest telephone exchange is chosen for the central point, the wiring between the controlling apparatus at the intersections becomes easy and does not need special cable plant for this purpose, since a pair of telephone wires is readily available to every point in the city.

The switching apparatus at the intersection can then be reduced to a set of relays operating the signals, controlled by a mechanism safely housed in the telephone exchange under the permanent supervision of the staff of the switchroom. This control mechanism will be free from dust, moisture and damage, common parts need not be repeated, and the interlinking scheme may be as complicated as is necessary for the most perfect control without difficulties due to wiring. The necessity to pack together a lot of apparatus in a small case disappears which disposes of a great deal of trouble in construction and maintenance.

Changes in the regulation can be made from a central point by a specially appointed police officer controlling the traffic distribution in the whole of the area. The working of the signals can be checked at the same place, without any difficulty. This place need not be the telephone exchange, because the whole of the mechanism, though mounted there, can easily be controlled from a distant point.

Out of these considerations has been developed the centralised road traffic control system in Amsterdam. The equipment follows normal construction in automatic telephony and is composed of normal telephone parts, the reliability of which is known and has been tested throughout many years.

General Method of Control.

Fig. 1 shows the general scheme of the method adopted.

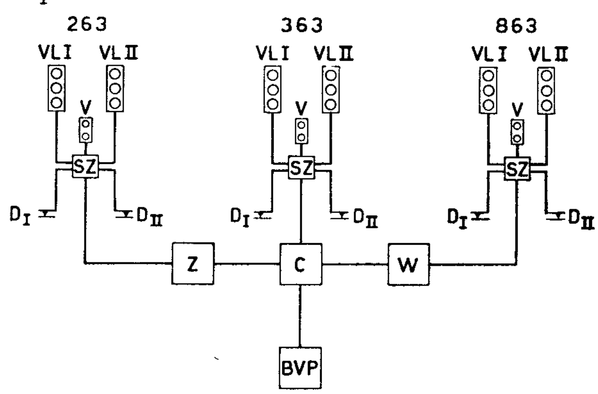


FIG. 1.—GENERAL METHOD OF CONTROL.

In Amsterdam the whole of the traffic in the city is controlled from one central point, viz., Police

Headquarters (BVP), which for this purpose has been connected to Central telephone exchange (C) by four pairs of telephone wires.

The intersections where traffic control is desired bear a three-digit number, the first digit of which characterises the exchange to which the controller (SZ) is connected. One to three pairs of wires are required, according to the controlling feature at that particular intersection. One pair is required for fixed time signals, two for the vehicle-actuated system and three where unidirectional detectors are necessary.

The signal lanterns, VL I and VL II, the lights for pedestrian crossings V and the detectors D I and D II are cabled to the controller.

The telephone exchanges Z, C and W are interconnected by four pairs of wires, the function of which will be described later. The number of wires between Z and C and between BVP and C ranges from two to four pairs, according to the facilities required.

Twelve different controlling features are provided for each intersection, but generally ten only are used. The required facility can be chosen by pressing a button at Police Headquarters, the number of the intersection having previously been dialled by means of an ordinary dial as used in automatic telephony.

When the number of an intersection is dialled, the working of the signals can be checked from three pilot lamps for each direction, reproducing the signals on the spot. In the telephone exchange all the signals can be permanently observed.

Finally a telephone connection can be established from the controller at the intersection (SZ) via the telephone exchanges (say Z and C) to Police Headquarters. This is particularly useful for the fault service and in emergencies. No extra wire is needed for this purpose.

Equipment at the Intersection.

Fig. 2 shows the normal equipment of a typical intersection. To avoid misunderstanding it may be stated here that in Holland, like nearly everywhere on the Continent, traffic keeps to the right.

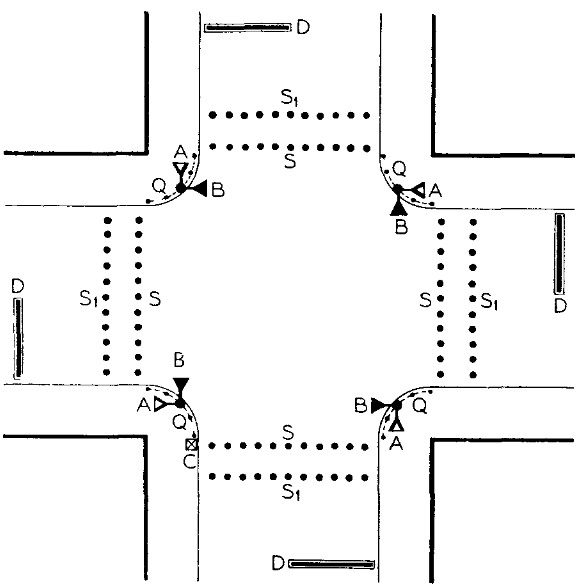


Fig. 2.—Equipment at the Intersection.

The intersection is defined as the area between the dotted lines S and the edges of the side-walks. S_1 are

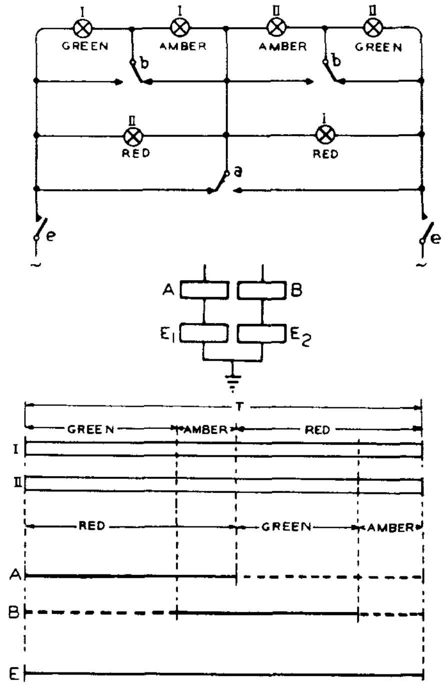


Fig. 3.—Control Circuit of the Signal Lamps.

the stop-lines. The spaces between S_1 and S are passages 8-10 ft. wide for pedestrians, the lines S and S_1 being nailed in the roadway. D are the detectors[1], situated about 90 ft. from the stop-lines, Q are fences preventing pedestrians from crossing the intersection at the wrong place, and C is the controller, merely a pillar holding the controlling relays.

The signal lanterns A and B, containing a red, an amber and a green light, are 10-12 ft. from the lines S. That on the nearside of the carriageway A has a height of 7-8 ft., the signal being repeated on the distant side of the carriageway B at the height of 8-12 ft., measured from street level to the bottom of the lantern.

The signal sequence is as follows :

Green : Proceed if safe to do so.

Amber : Stop before the stop-line, if this can be done without danger. Entering the intersection will be entirely at the risk of the driver.

Red : Stop and remain stopped until green appears.

Amber is shown only after green and before red, not after red before green. Two different lights are never shown simultaneously in the same direction as is done in England, e.g. red and amber.

The normal cycle has therefore the following four phases, the first colour applying to the main road, the second to the cross-road : (1) green-red, (2) amber-red, (3) red-green, (4) red-amber.

[1] *P.O E E J.*, 1936. Vol. 28, Part 4, p. 301.

Fig. **3** shows a simplified connecting scheme of the signal lamps at a normal intersection.

A, B, E_1 and E_2 are flat-type telephone relays, energised over one pair of cable wires, according to the time diagram shown in the lower part of the figure.

Phase 1, green I-red II, relay A operated, B released.

Phase 2, amber I-red II, relay A operated, B operated.

Phase 3, red I-green II, relay A released, B operated.

Phase 4, red I-amber II, relay A released, B released.

The relays E_1 and E_2 switch on the power circuit. Each of these telephone relays operates a power relay, having the same designation, which in its turn operates the contacts shown in the upper part of the diagram. It is easily seen that two lamps of the same colour, or two lamps of different colour in the same direction, can never be alight simultaneously. The eight relays are mounted on a shelf, which can easily be taken out for repair.

The controller also contains, when this is desired, a camshaft switch designed for manual operation of the signals, a power switch, fuses, a contact for a handlamp and a suppression device to prevent radio interference.

A pictorial view of the complete controller is given in Fig. **4**. The top of the controller can be opened as shown in Fig. **5**.

A police officer who wishes to operate the signals manually has to open the lid of the controller to reach the switch which enables him to change over to manual operation. As soon as the switch is operated a telephone communication is established between the controller and Police Headquarters, and the officer has to state the reason for switching over to manual operation. This switching over does not interfere with the function of the relays, which keep on working according to the planned schedule. When the police officer wishes to restore the controller to automatic operation, he informs Headquarters by telephone, pushes a button, and waits until a green lamp lights in the top of the controller, which indicates that the automatic system has the main road direction on green. Then he turns his camshaft switch to the corresponding position and switches over to automatic operation, the signals being synchronised with the automatic mechanism.

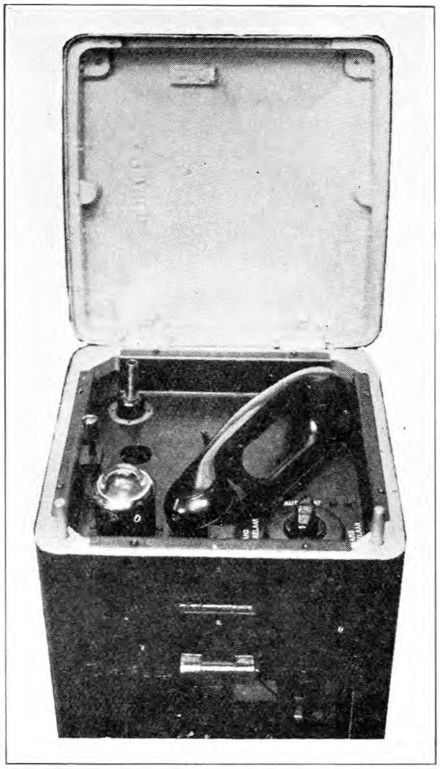


Fig. **5**.—Apparatus in the Top of the Controller.

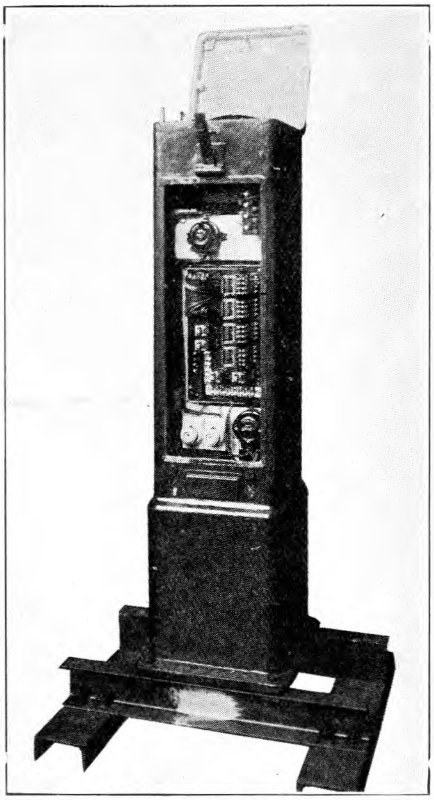


Fig. **4**.—The Controller (Opened).

By this method, intersections inserted in an interlinked system may be temporarily operated on a manual basis without disturbing the co-ordination.

Methods of Controlling the Traffic.

The following systems are in use in Amsterdam :

(1) *Fixed-time cycle system* with constant phase distribution.

(2) *Flexible fixed-time cycle system* with vehicle-actuated control in one direction, viz., the cross-road, having a maximum value of the green phase. A corresponding minimum value of the green phase is allotted to the main road. This minimum period is extended by the time not wanted by the cross-road traffic, the cycle time being constant.

Green in the cross-street direction appears only when the detector in this street has been operated by traffic arriving at the intersection during a red period. From this fixed point in the cycle begins the initial interval, designed to clear out the vehicles waiting between the detector and the stopline. This time having elapsed, each vehicle operating the detector extends the right of way by a certain number of seconds until there is an interval in the traffic flow which exceeds this time, or until the maximum time limit of green is reached. As soon as this critical interval or maximum time occurs, the right of way is transferred via amber to the main road. Detectors are mounted in the cross-roads only in this system.

(3) *Completely vehicle-actuated system.* Detectors are mounted in both directions, main road and cross-road. There are three methods of working depending on the right of way in the two directions.

(*a*) *With minimum and maximum time limits.* This feature extends the right of way up to a maximum period, which is timed from the moment green has commenced. As soon as the critical interval between the traffic in the one direction occurs the right of way is transferred to the cross direction whether there is traffic waiting or not. With no traffic approaching the intersection the right of way is again turned over after a minimum time. This feature works like a fixed-time cycle system with a very short cycle when there is no traffic and with a longer cycle when there is much traffic. The system is used when pedestrian crossings are included in a vehicle-controlled intersection.

(*b*) *With minimum but without maximum time limits.* This system works like (*a*), but there is no maximum right of way. It is very seldom used, because one direction is absolutely subordinated to the other, being unable to get the right of way as long as the latter claims green. It might be temporarily used when a procession is passing or when an immense amount of traffic has to be cleared from a congested part of the city.

(*c*) *With maximum only.* This is the normal system. The right of way can be extended up to a maximum, being timed from the moment the detector in the other direction has registered a vehicle asking for the right of way. This system therefore sets up a maximum waiting time. The signal remains on green, even when no traffic at all is recorded on the detector until the other direction claims the change over.

The Co-ordination of a Group of Intersections.

The co-ordination of a group of intersections is always a problem in itself, with which no ready-made scheme is able to deal.

An example will be taken of a number of intersections in a main thoroughfare, where the problem is to obtain the maximum capacity of the road. This entails a minimum of stops of the main road traffic flow. The following are the principal methods of interlinking of the intersections which could be adopted:

(*A*) *The synchronous system.* The signals are always exactly in the same phase at all the intersections. The duration of the green in the main direction must be sufficient at least to cover the full length of the street at normal speed, which necessarily implies a long cycle. This system employs the fixed-time cycle with equal phase distribution in all directions, and is liable to give too much of green to some of the cross roads. It involves as an average one stop on the whole length of the stretch.

(*B*) *The flexible synchronous system.* The intersections are worked according to the flexible fixed-time principle described above. There are detectors in the cross roads only, confining the green phase in this direction at all the intersections to the time necessary to pass the waiting traffic and that approaching the intersection within the time limit.

(*C*) *Progressive system.* This also has a fixed-time cycle feature, but the phases on the subsequent intersections, though being equal in length, are shifted in relation to each other in such a way that a vehicle entering the street at the beginning of the green phase and travelling at a predeterminated speed arrives exactly at the beginning of the green phase at all the subsequent intersections.

This system is the fastest way to dispose of the traffic in one direction, avoiding all stops in the main road, but traffic in the opposite direction in the same main road is often badly handicapped.

This feature therefore can be used only when there is a large difference in the density of traffic in both directions, e.g., one-way streets and roads with characteristic tidal traffic flow.

(*D*) *Flexible progressive system.* The signals at the intersections are worked according to the flexible fixed-time feature described above. The disadvantages for the traffic moving against the progression are partially compensated by the possible extension of the green phase derived from the not wanted right-of-way of the cross road.

This system also presumes the prevalence of traffic in one direction. When traffic in both directions is almost equal, only the features *A* and *B* are practicable.

In a main thoroughfare where the traffic distribution is liable to many changes during the day it will be necessary to change the system of co-ordination accordingly. The centralised traffic control at Amsterdam enables this to be done by pushing a button at Police Headquarters.

This is easy enough, but supposes a fixed schedule for each day. Therefore a new feature has been developed, such that traffic in the main road determines the method of control itself and at the same time changes the cycle time in relation to the density of traffic. This is:

(*E*) *The completely vehicle-actuated interlinked system.* Detectors are mounted in the cross roads only, working as described above, i.e., direct vehicle-actuated control in one direction at all the intersections.

At a suitable place somewhere in the main road a master-detector is mounted in each direction. This detector need not be near a particular crossing but is situated at a spot in the street where the amount of traffic passing is characteristic for the whole of the stretch. This place is so chosen that, as a rule, no traffic will stop on the detector, which is rendered inoperative when a red signal appears directly in front of it. Each detector records the number of vehicles passing. This may be " a " going north and " b " going south. A register in the telephone exchange determines the ratio :

$$x = \frac{a}{b}$$

and the density of traffic

$$y = \frac{a + b}{t}$$

t being the relatively short time during which " a " and " b " have been measured. The register automatically sets up the controlling feature in accordance with x and determines the cycle time according to y. The latter is checked every time a period t has elapsed. The changing of the controlling feature, however, occurs only when x for a rather considerable time has continually exceeded a predetermined value, thus proving that a characteristic change in the traffic distribution has taken place.

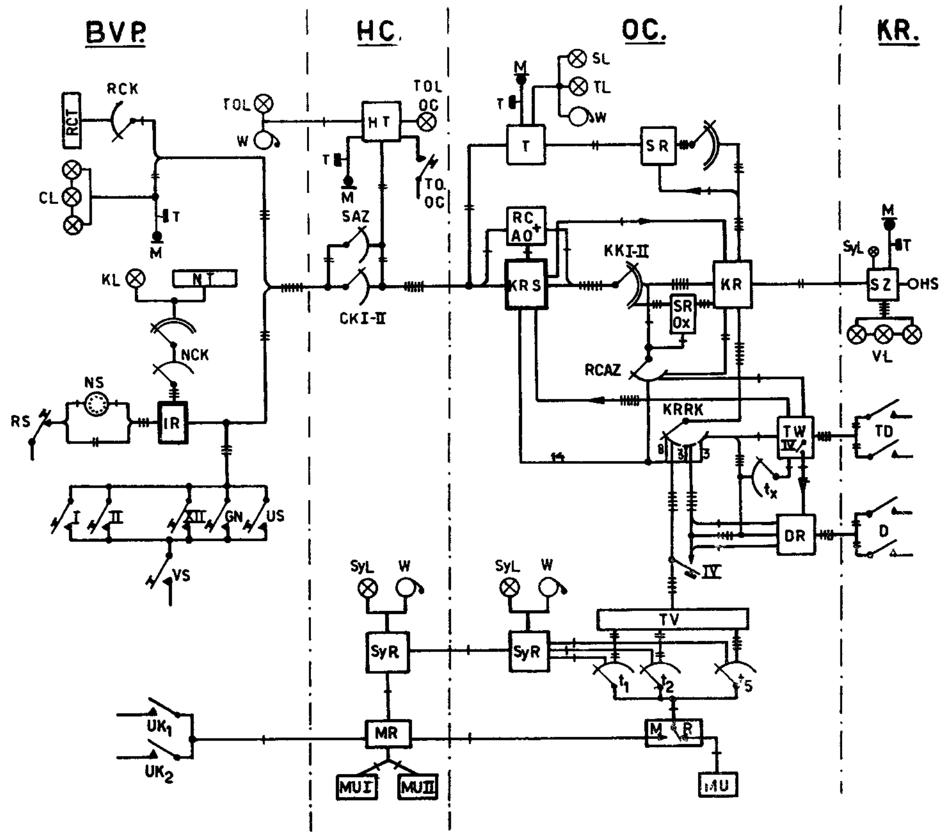


FIG. 6.—SCHEMATIC DIAGRAM OF THE COMPLETE INSTALLATION.
NOTE.—The cross strokes indicate the number of wires.

A typical application of the master detector is the following :

A number of intersections, being normally independent, is automatically interlinked when the master detector records in the register a certain minimum value of y on the main road. From this point the system works as described above. When the density of traffic for a certain time decreases below this value of y the co-ordination of the intersections is dissolved again. The master detector thus determines when the cross-road traffic shall be subordinated to the traffic in the main street and therefore when the intersections must be inserted in the co-ordinated system of the latter.

Some intersections, e.g. those with a lot of traffic turning to the left, cannot be controlled by a normal four-phase system. This also is the case at more complicated intersections, where many streets are converging or where a congestion of vehicular traffic necessitates special periods for pedestrians.

The centralised control, besides allowing the application of direct multi-phase features, moreover opens the possibility of analysing those multi-phase systems into two or more normal four-phase systems, this being only a matter of complicated interlinking which causes no special difficulties when the controlling apparatus is mounted in the telephone exchange. The advantage is obvious. The controlling mechanism can be standardised for all intersections, special features required being provided by separate intermediate interlinking relay sets.

The Principle of the Completely Vehicle-actuated Interlinked System.

Fig. **6** shows a simplified circuit diagram of the complete installation. The left part of the figure represents Police Headquarters BVP, the centre part Central Main Exchange HC, the right side an arbitrary sub-exchange OC, and the apparatus at the intersection KR.

To put into operation the controlling mechanism at some intersection, the officer at Police Headquarters dials the number of the intersection with the dial NS. The relay-set IR transfers the impulses (three digits) firstly to a double first selector CK I-II with six wipers and six wires, and secondly to the control-selector NCK which lights the pilot lamps KL, showing the number of the intersection and at the same time the lamp marking the spot on a map of the city NT. The last two digits are transferred to a double second selector KK I-II situated in the sub-exchange to which the intersection has been connected.

The next operation is the pressing of the keys VS and GN. The first is a general earth connecting key, provided to prevent wrong and undesired operations. By the second key the signal at the intersection is switched on and shows green in the main road direction. This remains until one of the keys I-XII is operated corresponding with one of the twelve controlling features.

The depressing of one of those keys sets up a relay combination in the relay-set KRS which characterises the feature wanted, thus designating a contact on the rotating switch KRRK. The relay-set KR belonging to the dialled intersection starts its hunting switch KRRK which moves to the marked contact.

Supposing that a fixed-time cycle feature has been chosen, the switch KRRK connects the relay-set KR with four wires via an intermediate distributing frame TV to one of the continuously rotating time switches t_1-t_5. The jumper wires on TV determine to which switch the four wires are connected and also their position on the contact bank. The time switches t_1-t_5 are driven from a master clock at a speed of normally one step every two seconds. The number of contacts on these switches being respectively 30, 36, 45, 60 and 90, it will be obvious that they represent cycles of 60, 72, 90, 120 and 180 seconds. The position of the four wires on the contact bank determines the duration of the four phases.

The relay-set KR under the control of the time switch supplies current to the relays E_1, E_2, A and B in the controller at the intersection.

Normally the time switches in the sub-exchanges are driven from the clock MU I or MU II, located in Central exchange, via the relay-set MR. The sub-exchange clock MU is provided for emergency use and is automatically inserted the moment the other fails.

The clocks MU I and MU II are brought into operation from Headquarters by the keys UK_1 or UK_2. There is a slight difference of speed between MU I and MU II, the slower one being used in wet weather. The relay-sets SyR contain the synchronising mechanism which keeps all the time switches exactly in synchronism.

Two checking devices are provided. The first checks the feature in operation on a lamp-strip RCT at Headquarters. The second device shows the working of the signals at the intersection by the lamps CL at Headquarters.

The keys I-VI correspond with six fixed-time features, and the keys VII, VIII and IX put into operation one of the three completely vehicle-actuated systems. In this case the rotating switch KRRK proceeds to the corresponding contacts, which connect the four wires of KR to a detector operated relay-set DR. This set contains a special time switch depending upon the impulses of the detectors D. By throwing key IV in the sub-exchange each of the six fixed-time systems can be changed into a flexible fixed-time system. The detectors are then working only in the cross-roads as described above.

The device SAZ (hunting switch) with SR (relay-set) has a double function. It signals a fault on the line to one of the intersections (lamp SL at the sub-exchange), and also provides the automatic telephone connection to Headquarters via SAZ to T and M (receiver and transmitter) as soon as a controller at the intersection is about to be operated manually. TOL is the calling lamp at Headquarters. The relay-sets HT and T are provided for telephone communication between the telephone exchanges, the intersection and Headquarters.

The key US at Headquarters extinguishes the signals at the intersection. The key RS releases the selectors NCK, CK I-II and KK I-II, and naturally the relay-set KRS, but leaves intact the controlling feature.

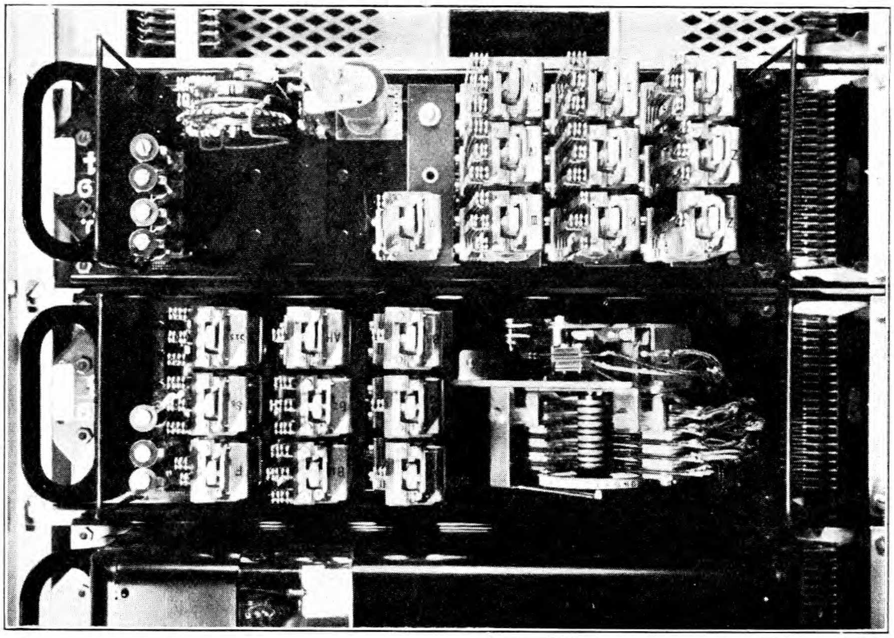


FIG. 7.—RELAY-SET FOR THE DETECTOR.

By dialling an intersection which is in action the officer at Headquarters can check the working, change the feature without extinguishing the lamps and disconnect.

The co-ordination of intersections working on the ordinary or flexible fixed-time features is an easy problem.

The group of interlinked crossings is characterised by a special group number. This being dialled, the relay-sets KR are likewise interlinked by means of the relays SROX and operated as a whole by one of the keys I-VI at Headquarters. It is obvious that they must all be connected to the same time switch and that the phase difference of the cycles at the various intersections will be defined by the place of the four-wire groups on the contact bank of the time switch. When the button IV in the sub-exchange is depressed the flexible system is put into operation

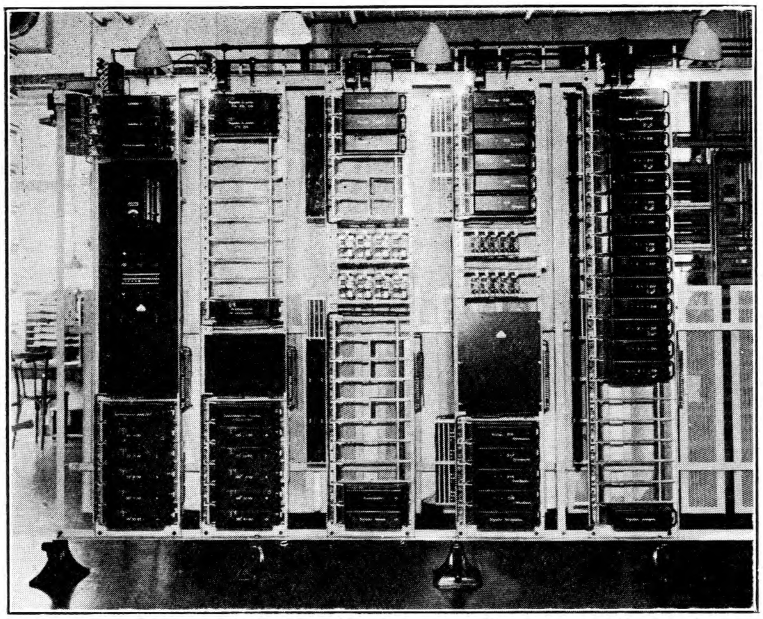


FIG. 8.—TRAFFIC CONTROL RACKS IN A TELEPHONE EXCHANGE.

using the detectors in the cross-roads as described above.

When the completely vehicle-actuated system is wanted a key at Headquarters is operated. The hunting switches KRRK of all the interlinked intersections then proceed to contact 10 and connect their relay-sets KR to the register relay-set of the master detector TW.

The whole series of intersections is thence controlled by a special time switch tx, the speed of which and thereby the cycle time is determined by TW. The register TW also has the power to move the switch KRRK, according to the interlinking scheme and the traffic requirements as shown by the records of the master detector. This changes the position of the four-wire groups of the interlinked KR sets on the contact bank of tx and thereby alters the method of co-ordination, i.e. synchronous, progressive in one direction or progressive in the other direction.

The connection TW to KRS is arranged to prevent Headquarters from operating KRRK at the same time as this is being done automatically by TW, and thus avoids confusion. The connection TW to DR has the same function as the key IV. As described earlier there is also a control which comes into action only when the traffic reaches a certain density. In this case a key at Headquarters only prepares the control circuit. The switch KRRK remains in the position where no interlinking exists and does not proceed to the tenth contact until the register has recorded the critical density of traffic. When the traffic again decreases there will come a value which induces the register to move the switch KRRK back to the former position whereby the interlinking is suspended again.

As the co-ordination of intersections depends only on the dialling of a collective number, it will be possible to provide for as many different combinations as wanted for an adequate traffic distribution.

Multi-phase systems can be handled in two different ways :

(*a*) The four-wire groups to TV and DR become multi-wire groups ;

(*b*) Two or more four-phase systems are interlinked by a set of relays and a sequence switch.

Both methods are used. The latter has the advantage of normalisation but involves a double set of cable wires to the intersection. From the foregoing description it will be seen that the circuit diagrams of the system must be rather complicated and their description goes far beyond the scope of this article. Photographs of the equipment are given in Figs. **7** and **8.** The three racks on the left of Fig. **8** are common for all the intersections connected to the sub-exchange ; the two racks on the right serve ten intersections.

The Controlling Apparatus at Police Headquarters.

Fig. **9** gives a view of this board. It will not need any further explanation. It may be observed that it is of remarkable simplicity, though being able to deal with the traffic control of the whole of the city of Amsterdam up to one thousand intersections.

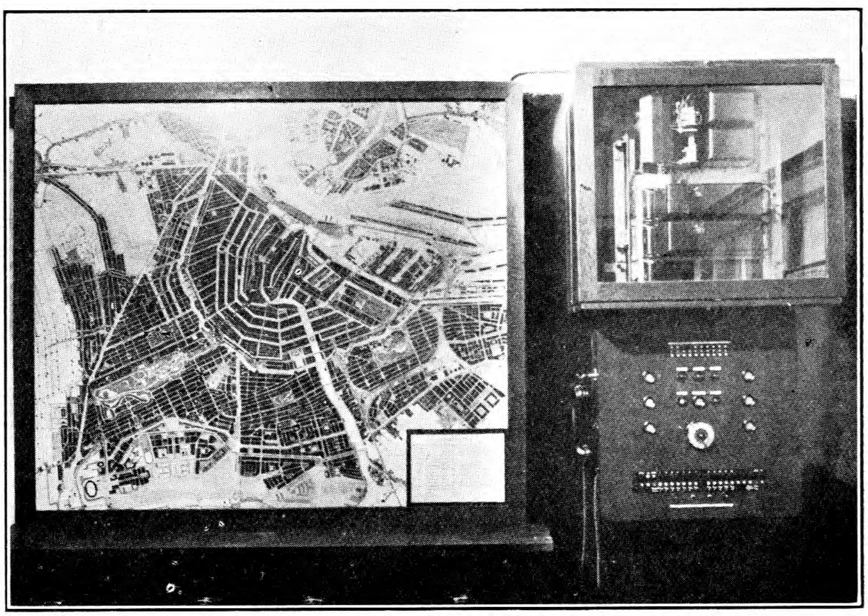


FIG. 9.—CONTROLLING APPARATUS AT POLICE HEADQUARTERS.

Traffic Measuring and Recording Apparatus.

The first thing required to measure the traffic is the establishment of a serviceable unit. Therefore

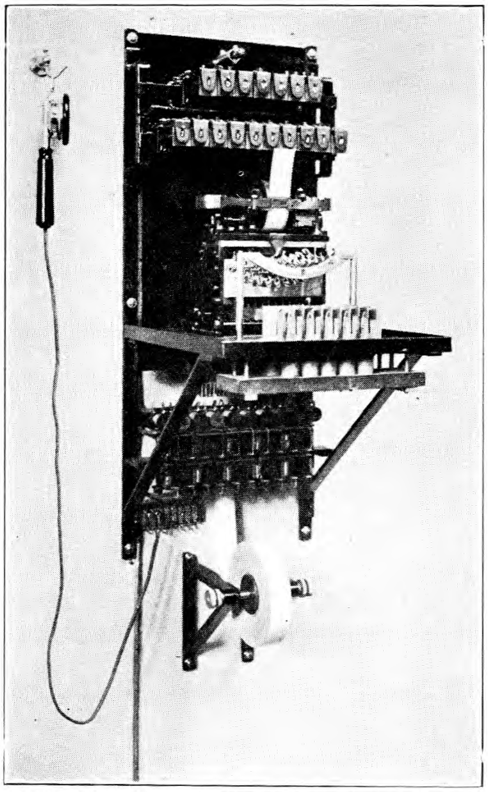


FIG. 10.—TRAFFIC RECORDING APPARATUS.

the impulses originating from the master detector when traffic passes are applied to a set of relays which transform them into normalised impulses of 300 milliseconds. This means that only detector impulses more than 300 milliseconds apart are registered.

The number of normalised impulses within a certain space of time is a suitable unit for measuring the density of traffic. As a matter of fact, this unit has not an absolute value but it is a practical one for comparing the density of traffic in the same thoroughfare at different points of time.

There are various methods of recording the impulses, but the most practical way has proved to be as follows :—The impulses are applied to a register consisting of three ten-point rotating switches, being able to register up to a three-digit number. At the end of a certain period, which may be the cycle with the fixed-time feature, or, for example, two minutes of green time with a variable cycle system, each digit of the number is transferred to a recording apparatus printing it on a paper tape.

Fig. **10** shows this home-made machine, which records alternately in black and red the figures of each direction of traffic.

Fig. **11** shows the traffic curves of the Leidsche straat (see also Fig. **15**), one of the busiest thoroughfares in Amsterdam. The curves A and B show the number of normalised impulses within two minutes in the N.-S. and S.-N. directions respectively, C being the sum of both.

The upper curve represents the ratio a/b when a>b and b/a when a<b.

There is also another recording device. The initial impulses of the master detector (not the normalised ones) are used to charge a condenser with a large resistance in series to the flashing point of a bridged neon valve. At the flashing point the number of impulses is recorded. The average length of the impulses, giving an idea of the average speed of traffic, can easily be calculated.

The centralised control system opens the opportunity for a great many traffic studies. The traffic, the working of the detectors, the function of the signals and their correlation, for instance, can be checked by means of a multiple-recording chronograph. From the data obtained may be derived much useful material for the investigation of traffic problems of all kinds.

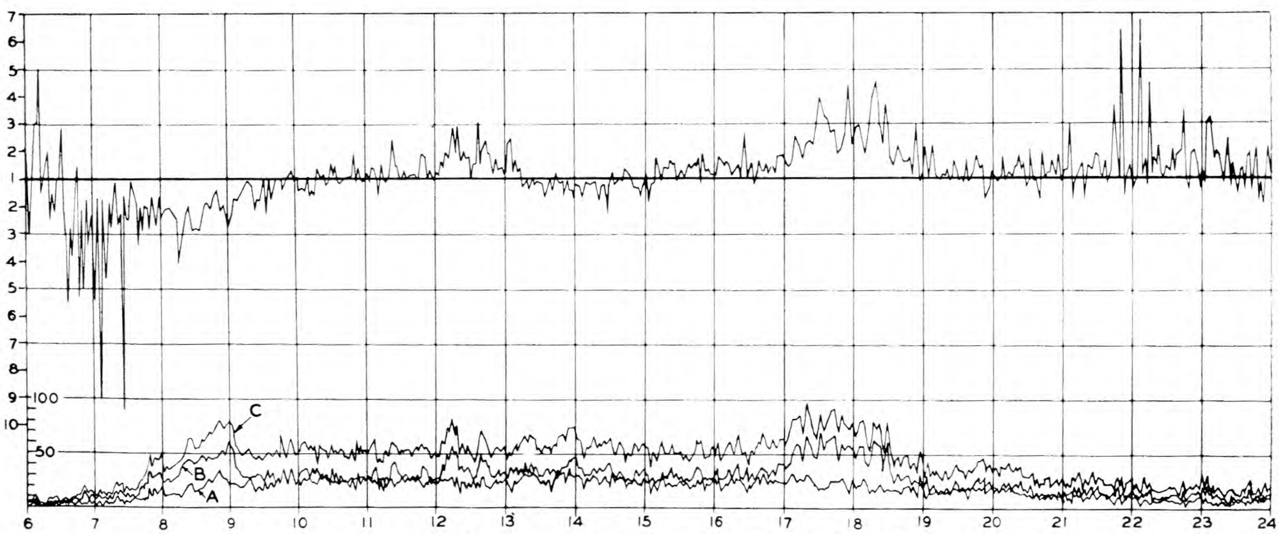


FIG. 11.—TRAFFIC CURVES OF THE LEIDSCHE STRAAT.

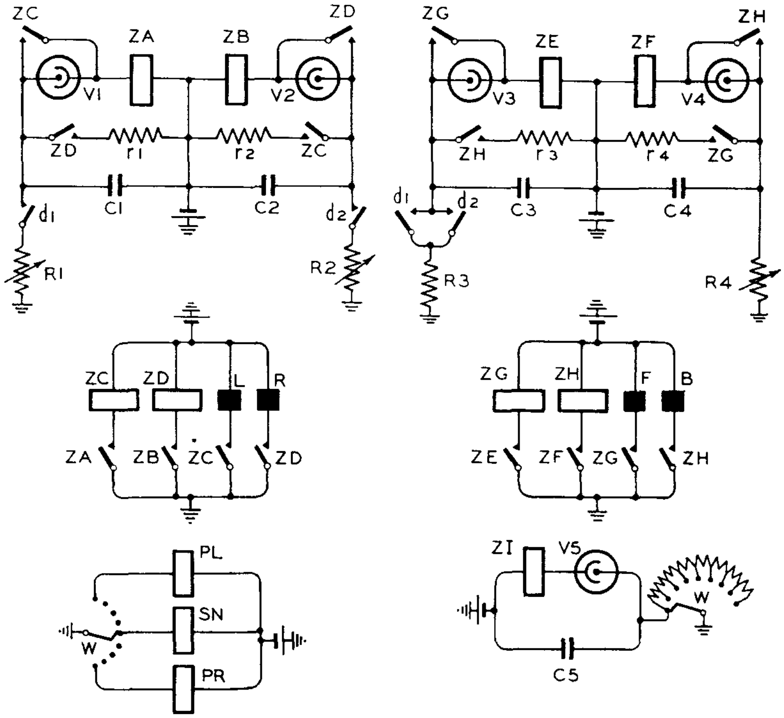


FIG. **12**.—CIRCUIT PRINCIPLE OF THE MASTER DETECTOR EQUIPMENT.

The Master Detector Equipment for Co-ordinated Intersections.

The impulses of the master detector are normalised as described above, divided into a 200 milliseconds current period and a 100 milliseconds no-current period, and fed via relay contacts and a large resistance to charge a condenser.

Fig. **12** is a simplified circuit diagram in which everything not essential has been omitted. d_1 and d_2 are the contacts mentioned above for the N.-S. and E.-W. directions. Each of these contacts charges the adjoined condenser C_1 or C_2 for 200 milliseconds per impulse through a variable resistance R_1 or R_2.

The condenser that first reaches the flashing point of the bridged neon valve V operates the relay Z, e.g. when the traffic N.-S. controlling d_1 is heavier than that in the S.-N. direction, the condenser C_1 will flash the valve V_1 and operate ZA before d_2 has been able to charge the condenser C_2 to the flashing point. ZA contact closes to operate relay ZC which discharges C_2 via a small resistance r_2.

If the S.-N. traffic should be the larger, V_2 will flash first and operate the relay ZB and thereby ZD. The essential part of the mechanism is a 25-point rotating sequence switch which can rotate in two directions, i.e., to the left and to the right. Its normal position is in the centre of the contact bank. In this normal position relay SN is operated over the wiper w. This relay SN causes the switch KRRK in Fig. **6** to move to the position required when traffic is equal in both directions, thus setting up the synchronous interlinking feature.

When the traffic distribution changes and, for example, relay ZC is operated, the magnet coil L is actuated and moves the switch one contact to the left. When the switch has been moved in one direction for a certain number of steps, relay PL or PR is operated, changing the interlinking system into the progressive feature, either to the city or from the city according to the exigencies of the traffic. Relays SN, PL and PR will each remain operated when the wiper leaves the contact until another relay is reached.

It will be seen that the apparatus only changes the interlinking system when the change in the traffic distribution has existed for a certain time. It does not function on incidental peaks in the traffic curve, but only when a continuous change has taken place. To accentuate this the rotating switch changes the resistances R_1 and R_2 at every step in such a way that conditions are biased against the detector having the right of way.

The apparatus controlling the cycle time of the interlinked crossings functions similarly. The contacts d_1 and d_2 charge the condenser C_3 in parallel. The condenser C_4 is charged to the flashing point of the valve V_4 in a certain time depending on the value of the resistance R_4.

The rotating switch is normally at zero and moves forward under the influence of ZG and backward under the influence of ZH. When the density of the traffic, i.e. the number of impulses within a certain time, increases, V_3 will flash first, and the switch moves forward, increasing the cycle time by adding resistance to the charging circuit of the condenser C_5, which governs the time switch tx (Fig. **6**).

With each forward step the resistance R_4 is decreased at the same time so that to move the switch forward again the traffic must increase still more.

When the traffic decreases the valve V_4 flashes first and moves the switch backward, thus shortening the cycle time.

A favourable consequence of this feature is that the phase difference at consecutive intersections increases and decreases with traffic. This is precisely what is wanted as the speed must decrease when traffic increases and the reverse. The amber phase is mostly kept constant.

The apparatus described allows a great many variations and therefore has a considerable adaptability for all sorts of traffic conditions.

Features Relating to Tramcar Traffic and Pedestrians.

A tramcar is a special element in road traffic and, transporting a great many people, it is entitled to some preference. Moreover, the tram is bound to its track and one waiting car blocks the whole line. To avoid this difficulty and in order to dispense with a special tramway phase the traffic police authorities arranged as follows :

A tramcar bound straight forward has to operate a detector and to wait for the right of way, the detector being in this case a contact in the overhead power wire.

Tramcars turning either to the left or to the right

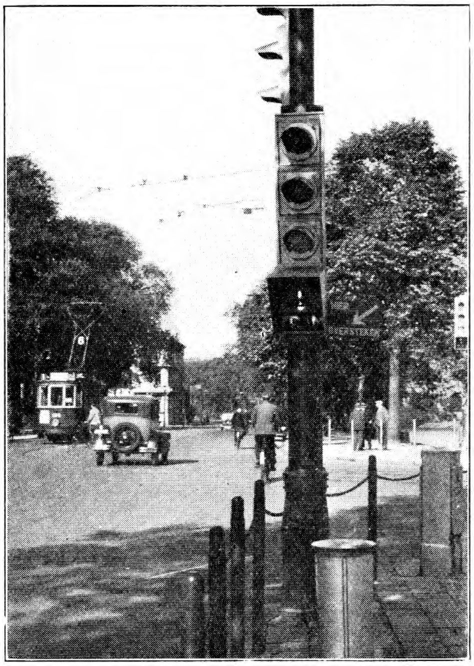


FIG. 13.—SIGNAL LANTERN SHOWING THE TRAM LIGHT.

move on, even when the signal may be red, thus penetrating the traffic flow. To avoid danger the tram lights a flashing warning signal appearing underneath the green signal. It can be displayed only with green or amber. Fig. **13** shows this signal, which is operated as long as the tramcar is in the curve. When necessary the tram extends the amber period sufficiently to clear the intersection.

The discrimination between tramcars going straight on and those turning either to the left or to the right is made by the electrically operated switches in the track.[2]

Sometimes special signal lanterns (Fig. **14**) are provided to control pedestrian crossings. These show only the green go-signal and the red stop-signal, lit from the controller at the adjacent intersection. When a tramcar is going to pass during the green phase a flashing warning signal is displayed. The green period is usually limited to 8-10 seconds, just sufficient to allow pedestrians to cross the road.

Some Special Applications.

Leidschestraat (Fig. **15**). This street with the adjacent squares is one of the busiest thoroughfares in Amsterdam. There are 15 intersections on the stretch of 0.6 miles between Spui and Leidsche plein. As may be seen from the traffic curves of Fig. **11**, traffic in this street has a typical tidal character and, therefore, three interlinking systems are used, viz., flexible progressive either to or from the city and synchronous. The master detector for both directions is located about the centre of the stretch and controls the switching as previously described.

The position of the master detector has been chosen on an intersection between the lines S (Fig. **2**) in order to avoid traffic stopping on the pad. Moreover the master detector is rendered inoperative during the red period in the main road.

Switching over from one system to another always takes place via the permanent green position in order to avoid the extinguishing of the lights during the changing of the system. In this period any light becoming green in the main direction according to the existing co-ordination remains green until it has to disappear in the sequence of the new co-ordination.

[2] The Electric Railway, Bus, and Tram Journal of October 16th, 1936, p. 153.

FIG. 14.—PEDESTRIAN CROSSING WITH SIGNAL LIGHTS.

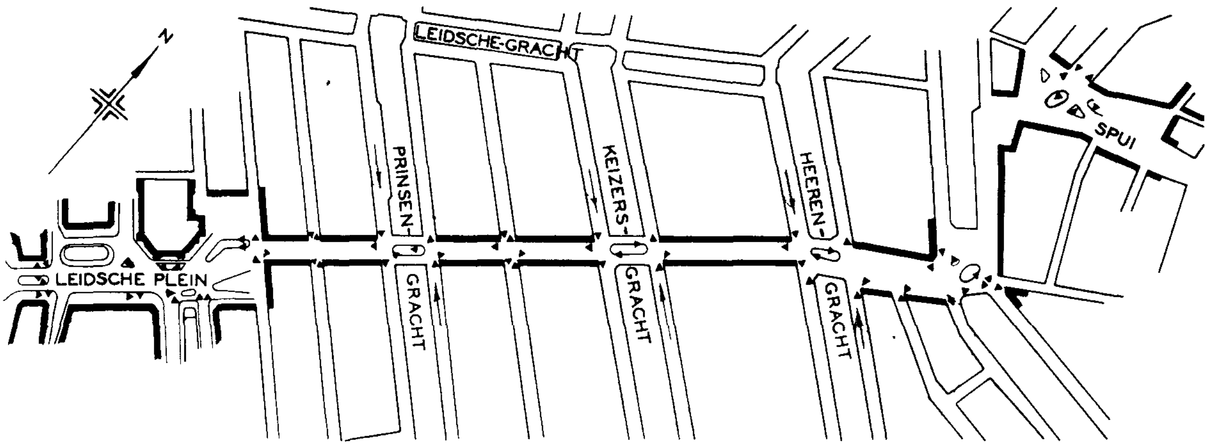


FIG. 15.—LEIDSCHE STRAAT INSTALLATION.

The master detector also controls the cycle time changeable from 60-180 seconds in accordance with the density of traffic.

Normal detectors in the cross roads confine the closing of the main road to the time needed to clear the traffic out of the cross roads.

Measurements show that with this system the street reaches in the peak hours 92 per cent. of its theoretical maximum capacity.

Museumbridge (Fig. **16**). There are rather busy intersections on both sides of the bridge. Normally they are controlled by their own four detectors in accordance with the completely vehicle-actuated system. When, however, the traffic flow across the bridge increases at peak hours above a predetermined level, both intersections are automatically interlinked and function in progression, thus relieving the traffic from stopping twice. For this reason the detectors D_1 and D_2 are connected not only in a normal capacity but also as master detectors to a register.

When the traffic across the bridge is approximately equal in both directions but as a sum exceeds a certain value, the interlinking is maintained but functions in synchronism. As soon as traffic decreases below this level the independent operation of both intersections is restored.

This is a typical case where the character of the traffic control must be changed many times a day.

Junction of Hobbemastraat and Stadhouderskade (Fig. **17**). This is an intersection requiring a multiphase control system, which has been obtained by interlinking four normal four-phase systems, by means of a special junction relay-set, containing a sequence switch as a phase distributor.

The principal crossing is formed by the left-turning traffic emerging out of Hobbemastraat passing detector No. 2 and the traffic following the Stadhouderskade passing detector No. 1. The control system at this intersection is normally the completely vehicle-actuated feature, working with minimum and maximum time. Occasionally a fixed-time cycle system is used. There are two tramway lines going east on the southern track which, coming from Stadhouderskade, turn into Hobbemastraat and one line proceeding straight on along Stadhouderskade. No tramcars leave Hobbemastraat (single track). Three lines going west follow Stadhouderskade on the northern track. 1a and 2a are the detector contacts in the power wire working in parallel with the road detectors No. 1 and No. 2. The discrimination is derived from the electrical switch in the track. Street cars turning to the right operate 2a, those going straight on 1a.

The street cars going west have no detector. They have a permanent right-of-way, occasionally penetrating the left-turning traffic emerging from Hobbemastraat. In this case they light the flashing warning signal underneath the signal lanterns Nos. 3 and 3a and the pedestrian signals 8 and 8a. A, B and C are passages for pedestrians guarded by signals.

The signals 15, 16 and 17 on the southern part of the pedestrian crossing C, the signal 11 for traffic

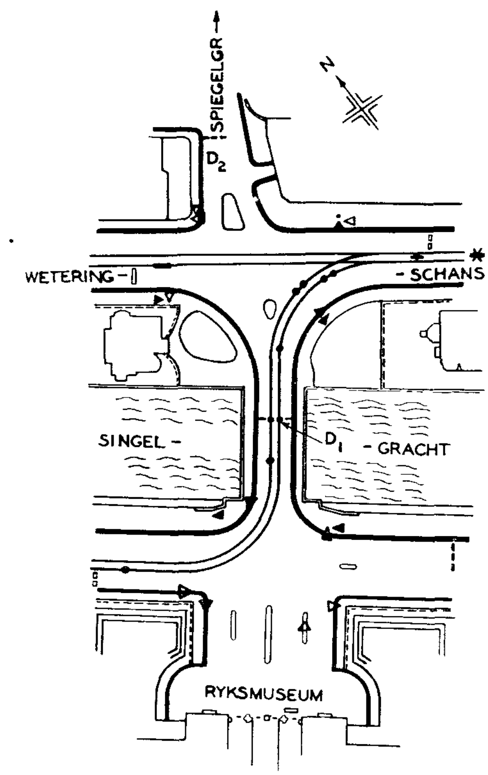


FIG. 16.—MUSEUM BRIDGE INTERSECTIONS.

leaving the Vondelpark, the signals 9, 5 and 5a on the southern part of the pedestrian crossing B, are all synchronous with the main intersection, but the green phase on 11, 16, 17, 5 and 5a and the red phase on 15 and 9 are limited to 10 seconds. Therefore the traffic from Stadhouderskade to Hobbemastraat will not be delayed more than 10 seconds per cycle.

(*b*) *for* n *co-ordinated intersections*, the expenses for the controllers nA, the cabling to the master controller nC^1 and the master controller itself E against those for the simplified controllers nB, the cabling to the telephone exchange nC and the interlinking apparatus F likewise located there.

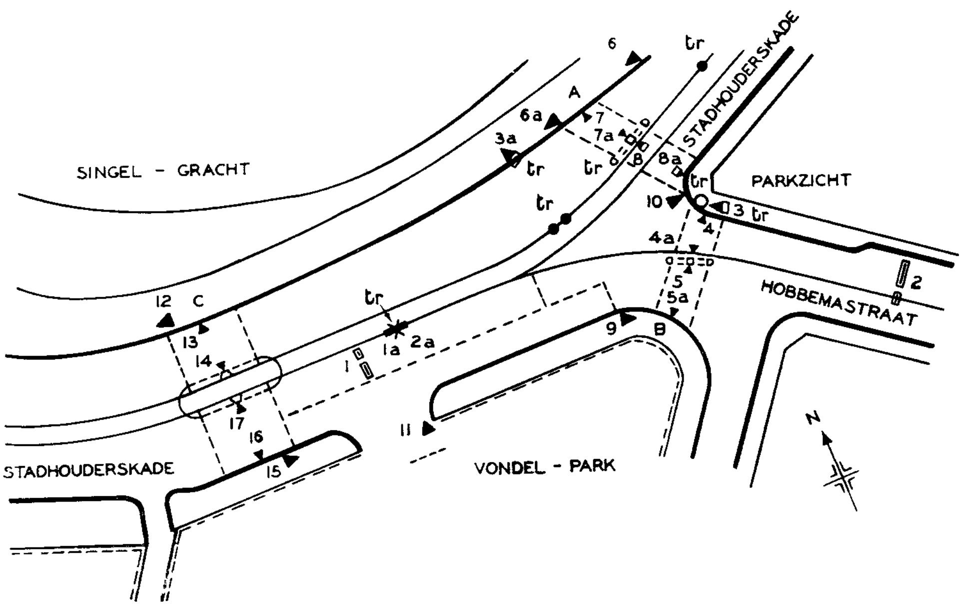


FIG. 17.—FOUR INTERLINKED SYSTEMS.

The signals guarding the pedestrian crossing A are also synchronous with the main lights 3, 3a and 10, but here the green phase for pedestrians is limited to 8 seconds. The pedestrian signals 4 and 4a are in phase with 10.

The signals at C have a phase difference in relation to the main intersection, sufficient to allow all traffic which has passed A and B to pass C. Here the signal sequence is progressive, and the pedestrian period is also limited to 8 seconds. The traffic proceeding west along Stadhouderskade, therefore, is never delayed more than 8 seconds per cycle.

The Economic Aspects of the System.

In order to discuss the economic possibilities of the centralised control system it will be necessary to make a comparison with other systems of equivalent quality having all the switching apparatus on the spot. For simplification, all items being equal in both systems may be omitted, i.e. signal lanterns, detectors and the cabling between them and the controller, thus eliminating at the same time the divergent views about the equipment of the intersections.

There is left to compare :

(*a*) *for independent intersections*, the expenses for the controller A, against those for a simplified controller B, plus cablewires C and central apparatus D ;

Example (*a*) :

It is evident that A > B.

D will depend upon the number of intersections per telephone exchange, say N.

$$\text{Let } D = \frac{P}{N} + Q$$

P being the expenses for the common part and Q for the individual part per intersection of the equipment in the telephone exchange. Finally the comparison must be made not on initial capital expenditure, but on the annual expenses, viz., depreciation, interest on capital and maintenance. It needs no stressing that the first and the last item will be considerably higher for material installed in the open air than for that safely housed and maintained in telephone exchanges. The annual charges may be estimated as follows in percentages of the initial investment :

	A	B	C	D	E	F
Depreciation	10	10	4	6	10	6
Interest	5	5	5	5	5	5
Maintenance	10	5	2	4	10	4
Total	25	20	11	15	25	15

Maintenance in B has been assumed to be less, because of the simple construction, absence of valves, etc.

The annual operating expenses for independent intersections in the local system will be:

$$K_1 = 0{\cdot}25\,A$$

and for the centralised system:

$$K_2 = 0{\cdot}20\,B + 0{\cdot}11\,C + 0{\cdot}15\,D$$
$$= 0{\cdot}20\,B + 0{\cdot}11\,C + 0{\cdot}15\left(\frac{P}{N} + Q\right)$$

If in a particular case the relations are:

$$C = 0{\cdot}2\,B,\quad P = 4\,B,\quad Q = B,\quad N = 20$$

then $K_2 = 0{\cdot}402$ B.

i.e. when $A > 1{\cdot}6\,B$ the centralised system would be the most economical solution for a fairly large city even if all the intersections are independent of each other.

Example (*b*):

In the centralised system the costs of interlinking intersections are zero with fixed-time features, whether flexible or not. Only when a variable interlinking scheme is used has the cost of the register to be added.

It may be taken that $C = C^1$. The cabling to the master controller is unlikely to be shorter when the wires are routed via the telephone cable network.

It will need no further calculation that the annual charges for co-ordinated intersections with local switching equipment are:

$$K_3 = 0{\cdot}25nA + 0{\cdot}11nC + 0{\cdot}25E > nK_2$$

and also that most probably

$$K_3 > nK_2 + 0{\cdot}15F$$

The conclusion is that, for co-ordinated intersections, the centralised system will be nearly always more economical than local equipment and that for independent crossings there still might be an advantage when more than 10-20 intersections are situated in the same telephone district.

The traffic control system at Amsterdam has been developed in collaboration with Siemens & Halske, Berlin, which firm has now standardised the equipment into two normally manufactured types, viz., for large cities, with twelve features per intersection as has been described, and a system with only one detector and one fixed-time feature for smaller cities. A comparison of the latter with the local equipment system seems to be still more in favour of the centralised system.

It might be stated finally that the average annual expenses per intersection at Amsterdam, everything included, have proved to be about one-third of the cost of control by means of a traffic constable from 8 a.m. to 7 p.m., overhead expenses included.

Summary of the Advantages of Centralised Traffic Control.

The advantages of the system which has been in use at Amsterdam since 1932, and has given complete satisfaction both to the public and to the Traffic Police authorities, may be summarised as follows:

(1) The system is able to deal with any traffic control problem that may occur either at the intersections individually, or in relation to the co-ordination of intersections, using a very simple equipment on the road and standard telephone material in the telephone exchanges.

(2) It allows twelve different control features at each intersection, easily interchangeable by pressing a button at Police Headquarters. Each of them is established by the position of four jumper wires on the intermediate distributing frame and each can be changed at the shortest notice. By dialling a number, intersections can be co-ordinated in various ways and in variable groups.

(3) Fixed-time cycle control and vehicle-actuated control are possible as well as any combination of them.

(4) It opens the opportunity to measure the traffic and to determine the control system accordingly. The operation of the system can be checked and times can be recorded by chronograph.

(5) In the telephone exchange the working of all the signals can be displayed simultaneously.

(6) There is a telephone connection from the controller at the intersection to Police Headquarters without any extra expense.

(7) Direct automatic fault detection is provided both for the lines and the detectors.

(8) No special cable plant is required for the interlinking.

(9) It is possible to vary the interlinking system and also the cycle time of co-ordinated intersections under the influence of traffic itself by means of a master detector recording the density of traffic and its distribution.

(10) As most of the switching material is housed in telephone exchanges, free from dust, moisture and damage, maintenance expenses are low and no special staff is wanted for this purpose. When faults occur spare relay-sets can be jacked in so that the signals are practically never out of order.

(11) Whatever alterations may be wanted in the control system, the controller at the intersection remains intact. Repeated mounting and remounting on the street is avoided.

(12) Space to accommodate equipment becomes a secondary question.

Tunnelling Work in Underground Line Construction

A. T. SOONS

A description is given of a scale model used to demonstrate underground tunnelling construction. The author also describes the method of construction of tunnels for underground duct work.

Introduction.

IN lecturing to Works Supervisors at the Training School, Dollis Hill, upon underground construction contract work one is handicapped by inability to demonstrate "the real thing." Lecturers whose subjects embrace automatic telephony, teleprinters, or telephone transmission have no difficulty in demonstrating to students actual apparatus under service conditions. In connection with underground construction it is possible to exhibit samples of sands and aggregates, engineering bricks, and specimens of steel reinforcement, but that is about the limit of practical demonstration. It is out of the question to construct full-size trenches or manholes for the benefit of successive classes. With the object of explaining as fully as possible an intricate aspect of excavation work the writer has made a scale model of a typical tunnel layout (Fig. **1**), and it has been suggested that photographs and a description of tunnelling may be of interest to readers of this journal.

Tunnelling as an Alternative to Trenching.

Tunnelling is a relatively costly method of laying conduits and is only resorted to when one or more of the following conditions apply :—

(1) Where traffic congestion forbids obstruction of a highway by open trenching.

(2) Where there is such congestion of underground plant of all classes as to necessitate laying of new plant at an abnormal depth.

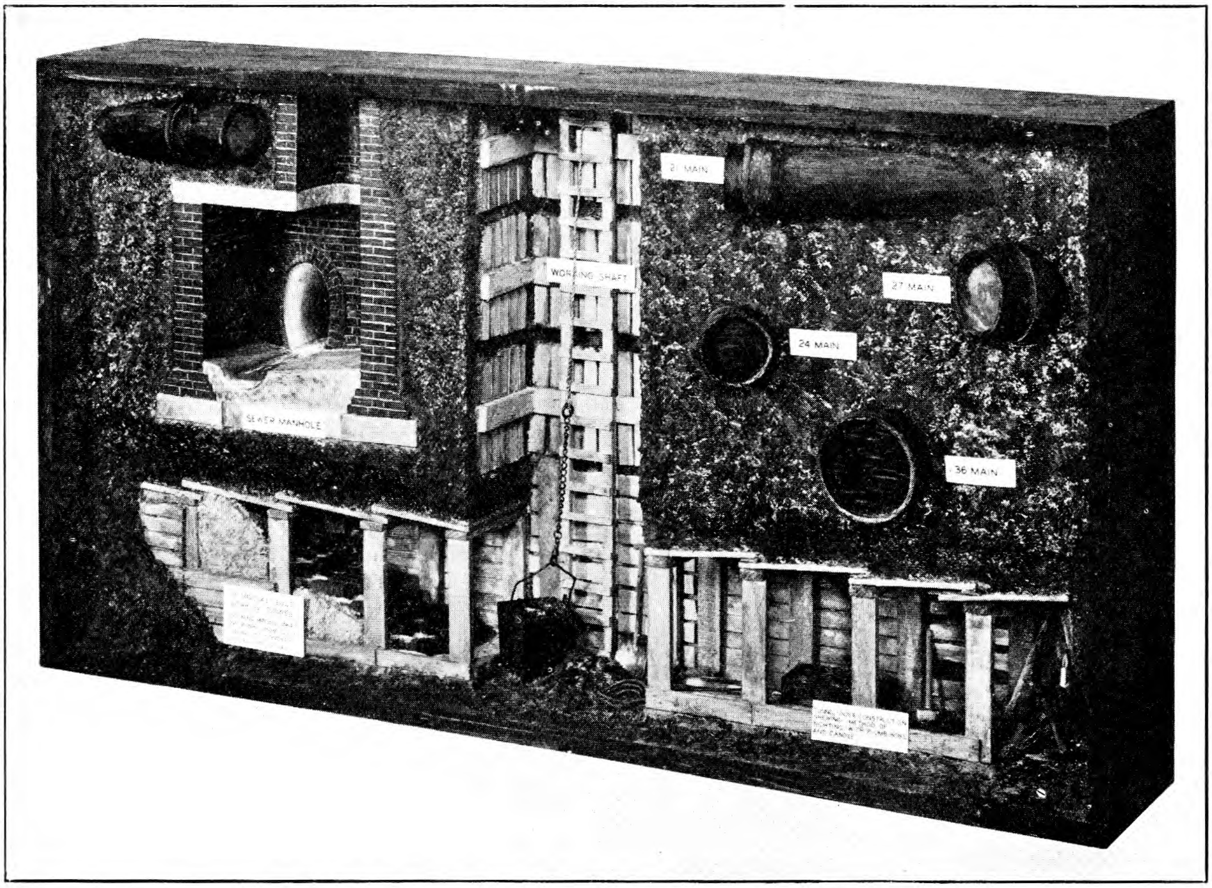


FIG. **1**.—SCALE MODEL OF WORKING SHAFT AND TUNNEL.

(3) The presence of a large obstacle such as a large underground chamber or sewer, as in Fig. **1**.

(4) Rock subsoil, where comparison beforehand indicates that the high cost of tunnelling shows a saving on the still higher cost of removing a large volume of rock by breaking down from the surface.

The cost of tunnelling may be as much as, say, £11 to £12 per route yard for the construction of a 36-way octagonal duct route, and to this figure must be added the entire cost of sinking and subsequently restoring as many working shafts as the nature of the tunnel requires.

The rate of progress is generally slow since one man only can find elbow-room at the tunnel-head. A fair proportion of the cost of tunnelling is expended in back-filling with concrete or hardcore in order to meet the usual and quite reasonable demands of highway authorities.

On this point the Post Office has reached general agreement with the Institution of Municipal and County Engineers and associated public bodies and this agreement is now used as the working basis for Departmental works.

Practical Considerations.

Due to the cost of excavation, including timber abandoned in situ, and the above-mentioned costly back-filling, it is in the Department's interest to restrict the tunnel height and width to limits dictated by the sectional area of the duct formation under construction or to the minimum area in which a miner can work with reasonable freedom. A maximum height of 1 ft. 9 ins. above the topmost tier of ducts, with a minimum total height of 4 ft. for any tunnel,

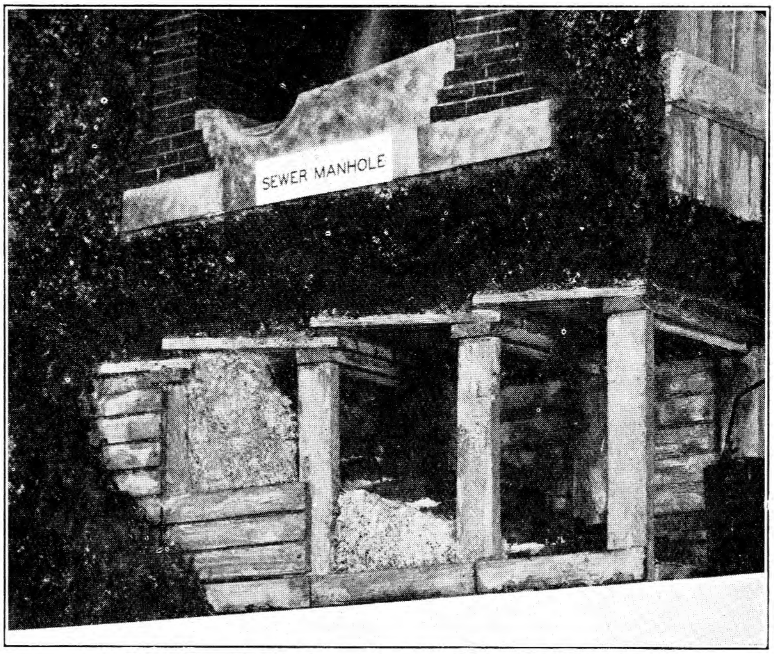


FIG. 2.—OCTAGONAL DUCT-LAYING IN TUNNEL.

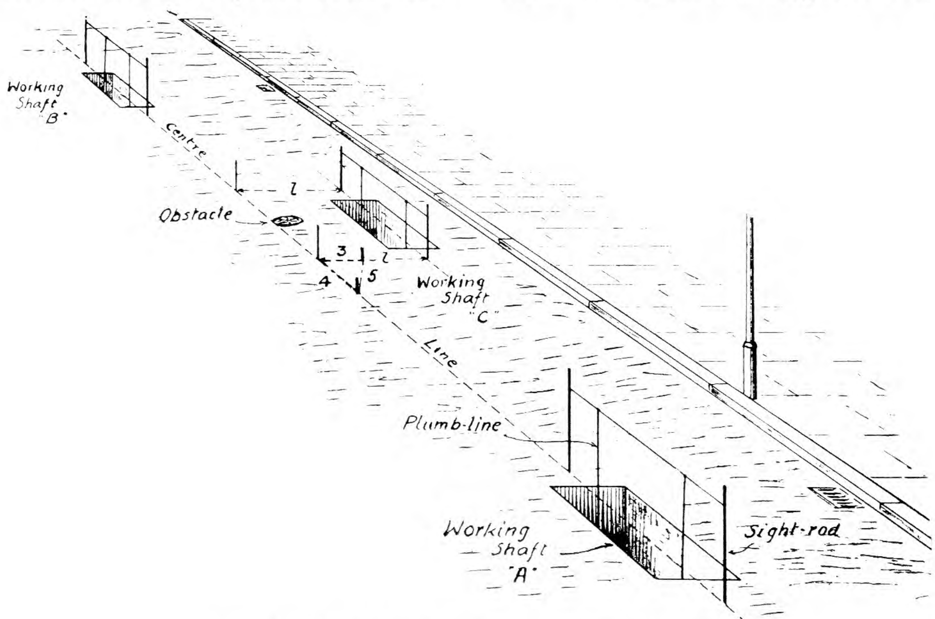


FIG. 3.—CENTRING THE TUNNEL ABOVE GROUND.

is adequate, in the writer's personal experience, for this class of work. In order to take advantage of such conditions it is necessary to bring all tiers of ducts forward together in one block and to fill in above them before the empty space between ducts and roof extends beyond arm's length (Fig. **2**).

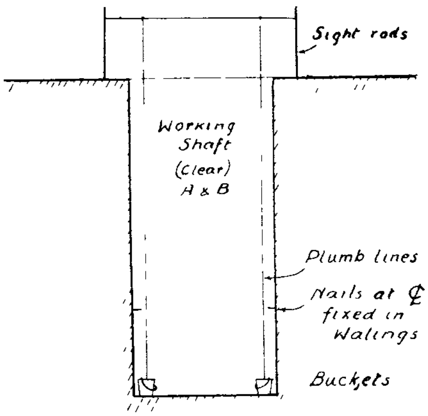


FIG. **4**.—TRANSFERRING CENTRE-LINE TO BOTTOM OF SHAFT.

Additional reasons for restricting the tunnel heights and for filling as one goes are that the back-filling concrete (where octagonal ducts are concerned) is invariably of good quality (3-2-1) as used in surrounding the octagonal duct formation, and that the tendency of the concrete filling to " slump " must be kept under control. Good concrete is employed for filling-in where a lean concrete would otherwise suffice, because it is impracticable to handle two mixes simultaneously, and " slumping " must be controlled or voids may develop. Such faults may remain masked for many years, to be revealed ultimately when the abandoned timber decays and the ground above takes up fresh bearings.

Supervision of Tunnel Construction.

Extravagant as it may appear, it has been found worth while to detail an experienced supervisor to remain with the duct layer throughout the duct-laying and filling operations. This supervision is additional to normal requirements above-ground on other work (i.e. manhole-building or duct-laying in trench) going on at the same time. The justification for the employment of the additional supervisor lies in the fact that failure to insert the full quantity of concrete of the requisite quality is liable to cause subsidence of streets and adjacent buildings with consequent risk of injury to person and damage to Post Office and other plant. Experience of breaking down on existing octagonal duct routes for interception by new manholes has revealed, now and then, the absence of the full thickness of concrete, and apart from the monetary loss to the Post Office the risk as indicated above is considerable. It is therefore truly economical to post a good supervisor at the tunnel-head not only to check quantities but to ensure a sound and satisfactory job. It is impossible to locate water leakages in the completed work, and equally useless to argue about them ; reliance must be placed in a system of close and continuous supervision which takes nothing for granted.

Although not demanded specifically in the contract, it is of mutual advantage that the contractor shall pull the mandrels through the completed portion of the work two or three times daily in order to detect any settlement due to the " green " condition of the concrete. Such tests focus attention upon faults while there is still time to correct them at minimum cost.

It would afford little satisfaction to the Post Office to debit its contractor with the value of an unusable duct " way " calculated on the cost per yard since the matter at issue is the loss of cable revenue.

Operations on Site.

It may be assumed that all available particulars regarding the depth and position of foreign plant have been obtained before reaching a decision to tunnel. A survey of the line of route should be made, including conditions of the road surface and existing dilapidations evident in property adjacent to the route. It is well to obtain good photographs of such defects as cracks in walls, settlements, and any adjacent buildings " out of plumb."

Pilot-holes. Pilot-holes should be sunk at selected points as a check on the reported positions of existing plant and, if the pilot-holes disclose favourable conditions for tunnelling they may be opened out to form working shafts. When all the shaft requirements have been met sighting rods may be set up and the centre-line of the tunnel ranged above-ground. Fig. **3** illustrates the process and shows an intermediate shaft off-set from the centre-line. In one of the off-set measurements the well-known use of the " **3-4-5** " method of setting out a right angle is included.

Working Shafts. These are set out so that the centre-lines of the shafts coincide with the centre-line of the tunnel.

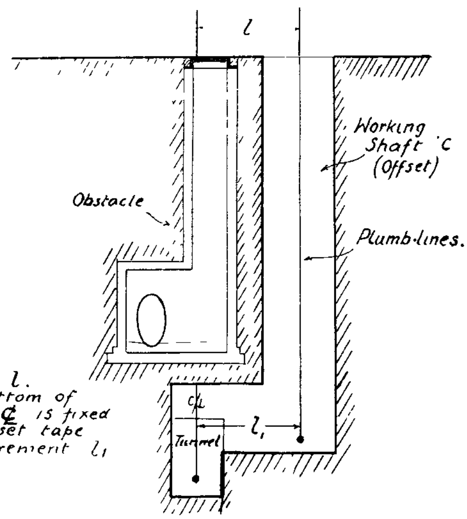


FIG. **5**.—TRANSFERRING CENTRE-LINES WHEN SHAFT IS OFFSET.

The next operation is to transfer the centre-line above the shafts to the bottom. Plumb-lines carrying fairly heavy plumb-bobs are lowered into the shafts as shown in Fig. **4**. The plumb-bobs may be steadied by immersion in buckets of water at the bottom of the shaft. With the plumb-lines at rest, the line of sight is fixed on each wall by driving a stout nail into the timbering of the shaft.

Further sights prolonging this line between the two nails on to other plumb-lines in the tunnel should then fall immediately beneath the same alignment above ground. It should be mentioned that working shafts do not always afford a clear drop from top to bottom owing to the presence of foreign plant. Fig. **5** is based upon a typical example. Great care is therefore necessary in transferring plumb-drops in order to arrive at the bottom without serious error.

Tunnel Driving may now be commenced, working simultaneously at both faces of each intermediate shaft, and as soon as sufficient earth has been excavated the "frame" is placed in position and the crown-boards driven fully home, their ends resting upon the top of the piling-board. At this stage the side-boards are forced into position. In firm soil the side-boards will be spaced openly, and in wet or unstable soil closely. Exceptionally it may even be necessary to drive close side-boarding forward along with the crown-boards in order to cope with very unstable soil.

It will be seen that the weight of earth in the roof is carried via the crown-boards and head-trees to the side-trees, which in turn rest upon foot-blocks; therefore the foot-blocks must be of ample area to distribute the load.

Fig. **6** shows the method of placing timber in the tunnel. As it is impossible to recover any timber from the tunnel, all timber should be sufficiently stout for

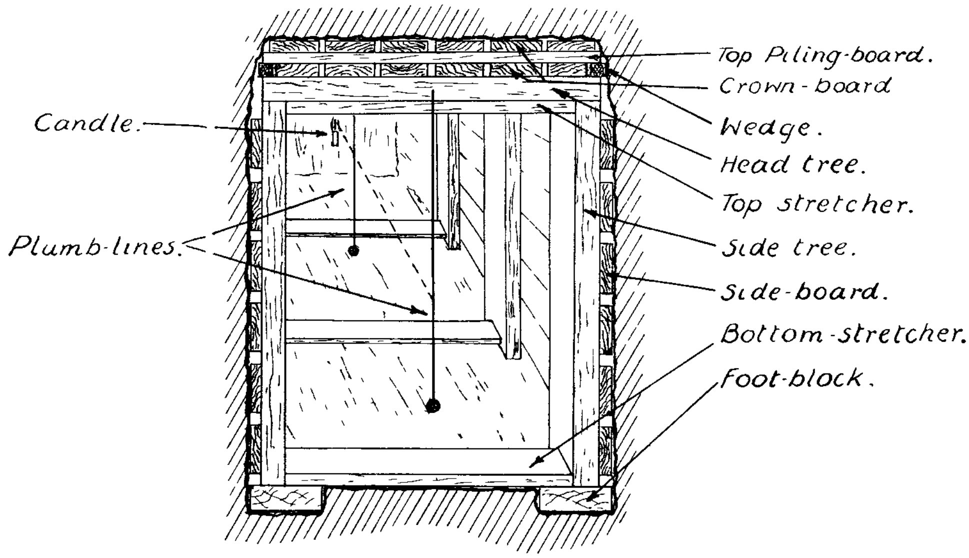


FIG. **6**.—METHOD OF FRAMING TUNNEL.

first "frame" of timber is placed in position at the mouth of the tunnel. A "frame" comprises two Foot-Blocks, two Side-Trees, one Head-Tree, one Top Piling-Board, two Wedges and Top and Bottom Stretchers. (Fig. **6**.) The "foot-blocks" are sunk flush with the tunnel floor. The "side-trees" are cut "full" so that when knocked into an upright position the "top piling-board" is forced tightly against the underside of the earth roof. The top and bottom stretchers are now forced into position between the side-trees to prevent side compression of the earth dislodging them.

The "crown-boards" are slipped into the slot between the top of the head-tree and the piling-board, and as the tunnel-driving proceeds the crown-boards are knocked forward. (Fig. **7**.)

At the working face the unsupported ends of the crown-boards are supported temporarily by means of a T-shaped piece of timber known as a "Timberman's Crutch," to protect the miner against falls of earth from the roof. When the crown-boards have been advanced almost to their full extent, a second its purpose but not so thick that its ultimate decay in the earth would cause voids that may result in subsidence.

Sighting in Tunnel. In tunnels required for Post Office duct work the degree of accuracy employed in tube railway or sewer grading is unnecessary and all sightings may be taken and fixed with nothing more elaborate than a couple of plumb-bobs, a lighted candle, and a few nails for fixing the centre-line permanently. A level course, or any degree of rise or fall, can be carried in from the mouth of the tunnel by means of a straight-edge and spirit-level.

If any "lateral sets are required, e.g., to follow the curvature of a road, it is probable that the number of working shafts normally required will afford all facilities for securing fresh centre-lines and no attempt need be made to set out elaborate curvatures in the tunnel itself.

Regarding the lengths tunnelled between shafts, it is recollected that in one job 3 sections comprising 377′ 0″, 247′ 0″, 132′ 0″ respectively, at an average depth of 23′ 0″, was looked upon as exceptional, proving rather stuffy for the men working in the tunnel.

It is recommended that sights from the plumb-lines in the shaft into the tunnel should first be taken at the placing of the third " frame " of timber, (i.e., about 7′ 0″ into the tunnel, the frames or side-trees being placed at 3′ 6″ centres). The centre-line should at this stage be found, and nail-marked, on the third head-tree by means of sights from the plumb-lines in the shaft to one suspended from the head-tree.

Future sights can be taken by ranging between the shaft plumb-line nearest the tunnel mouth and that suspended from the third head-tree, on to the wick of a lighted candle held in the face of the heading and moved as directed until in agreement with the tunnel centre-line. (Fig. **6**). As the work proceeds the plumb-lines are moved forward, by first taking a sight upon the candle and then moving the back line to a forward position. An occasional back check should be made on to the old positions.

Excavation. There is room for none but the miner himself to hew at the face and to tip the spoil on to the canvas sheet or into a small box behind him. Another man will draw away the excavated earth along boards placed on the floor of the tunnel (an operation known as " dragging the badger ") to the pit where it is raised to the surface by throwing it up in stages, or by bucket and windlass. (Fig. **1**).

Wet Conditions in Tunnel. A rising tunnel may be drained by means of a rubble drain laid in the bottom of the tunnel from the working face back to the shaft and pumping effected from the shaft-head.

A falling tunnel, in which water tends to run down and impede the miner at his work, should have a similar drain graded to fall in the opposite direction and intercepted by a series of sumpholes, at which the water can be pumped or baled to successive higher levels until the shaft is reached.

Conclusion.

By means of careful sighting and levelling it is possible to drive two headings to meet at midspan without fear of serious error.

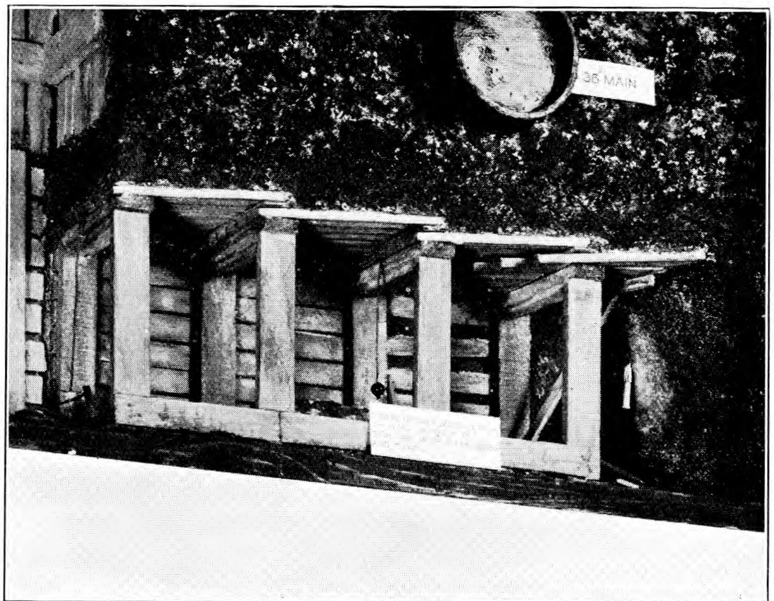


FIG. **7**.—METHOD OF SIGHTING WITH PLUMB-BOBS AND CANDLE.

It is neither necessary or desirable to attempt long spans as progress will be hampered by the extra time required for bringing out the spoil and taking in ducts and concrete. There is also the important question of fresh air supply and fatigue of the men working at the end of a long burrow, as they may suffer from foul air, and on that account the tunnels should not exceed 100 ft. in length unless ventilation can be arranged.

In addition to demonstrating the actual method of tunnelling the model also serves to illustrate the method of arriving, for costing purposes, at quantity checks of volumes of concrete and timber and spoil excavated.

An Accurate Method of Sub-Localising Cable Faults when No 'Good' Wire is Available

G. H. METSON B.Sc.(Eng.),A.M.I.E.E.

The author describes a new and speedy method of sub-localising faults in underground cables when no reliable test wire is available. The description of the method employed is followed by an explanation of the theory involved.

Introduction.

THE localisation of full-earth cable faults when no good wire is available has been rendered less difficult in the past few years by the introduction of an alternating current method of test.[1] The A.C. test gives an accurate first localisation but cannot be used for the actual sub-localisation of a fault. Underground staff are therefore finally forced back on the alternative of running a mile or so of covered conductor for use as a good wire or of using the notorious " open and closed " resistance test for sub-localisation. The first of these alternatives is only practicable on open rural roads and the second is so unreliable that it is only used as a last resort. The unnecessary opening of cable joints and ground holes is therefore a common feature in the clearance of such faults.

To fill this want a precision method of localising full-earth faults has been devised and is described in this article. The method has been investigated in some detail and has the following advantages :—

(*a*) Simplicity of operation. A capable underground foreman can be instructed in the use of the test in a few minutes.

(*b*) Portability. The equipment is readily portable and can be set up at the roadside, or at a cable or amplifier hut, in two or three minutes.

(*c*) Accuracy. With reasonable care in testing the localisation error is not likely to exceed 2 per cent. of the test length. The method appears to give equally good results on long or short cables.

(*d*) Speed of testing. The equipment can be set up and a localisation effected in less than 10 minutes.

(*e*) Polarisation at the fault. This appears to have little effect on the test despite the fact that the method is a D.C. one.

(*f*) Only simple equipment used. The method is a double-ended one with identical end sets. Each of these consists of a 1,000 ohm Sullivan slide-wire, two milliammeters, a 120 volt dry battery and a rough controlling variable resistance of about 2,000 ohms.

The main limitation of the method appears to be a progressive decrease in accuracy due to insensitivity if the insulation resistance of the cable rises much above 30,000 ohms. The fault resistance of cables with a heavy earth fault is, however, usually of the order of 100 ohms to 5,000 ohms and the limitation is not likely therefore to affect the utility of the test.

Description of Method.

The method may be described as a double-ended, constant current, slide-wire test. Its essential features are shown in Fig. 1. The end sets are identical and it is necessary therefore to describe only one of them.

The 1,000 ohm slide-wire S, S_1 is fed from the 120 volt dry battery with current measured and controlled by the milliammeter I and resistance r^1 respectively. The faulty line pair is connected to the P terminals of

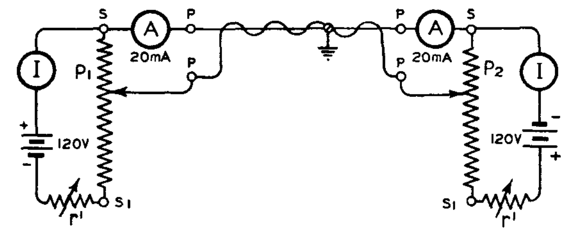


FIG. 1.—CONNECTIONS OF THE TEST.

the slide-wire and the current is measured by the line milliammeter A. The voltage applied to line is thus proportional to the slide-wire dial settings P_1 and P_2.

The polarity of the slide-wire batteries is so arranged that the voltages applied to the faulty pair at its two ends tend to assist each other. This is assured in the following manner. The slide-wire at the controlling end is adjusted to pass say 5 milliamps to line. The distant end slide-wire is set to zero and the current received from the far end noted. The slide-wire P_2 is then set to some value greater than zero and the line current should increase. If the current decreases then the polarity of the battery must be reversed.

Both slide-wires P_1 and P_2 are adjusted until the line milliammeters A both read exactly 20 milliamps. A balance may be obtained in a few seconds but this must be held for a full five minutes during which time the line milliammeters are tapped continuously and the values of P_1 and P_2 slightly adjusted until a perfectly steady state is achieved. When the line milliammeters at both ends have registered exactly 20 milliamps for a minute without any visible variation, the testers may be satisfied that a state of balance has been achieved. At each end the value of the slide-wire setting P_1 or P_2 is now read and the local currents i_1 and i_2 in the terminal battery circuits noted on the milliammeters I.

Then, if,

Test Measurements:

P_1 = Slide-wire setting at controlling end.
P_2 = Slide-wire setting at distant end.
i_1 = Current in milliammeter at controlling end.
i_2 = Current in milliammeter at distant end.

[1]*P.O.E.E.J.*, Vol. 23, p. 43.

Constants:
- l = length of cable under test in miles.
- r = loop resistance per mile of cable under test.
- a = resistance of each line milliammeter A.

x = distance of fault from controlling end.

$$x = \frac{P_1 i_1}{P_1 i_1 + P_2 i_2} l + \frac{P_1 i_1[F(P_2)+a] - P_2 i_2[F(P_1)+a]}{r(P_1 i_1 + P_2 i_2)}$$

The second term in this expression compensates for the introduction of resistances into the line circuits by the terminal slide-wires. It contains terms, $F(P_1)$ and $F(P_2)$ which are functions of P_1 and P_2 respectively. These terms are obtained direct from a curve P/F(P) which is set out in its generalised form in Fig. **2**. From this general curve can be obtained the value of F(P) for any value of P from 0 to 1,000 ohms. The prefix " h " is substituted by the " hundred " digit of P and the corresponding value of F(P) read as an ordinate.

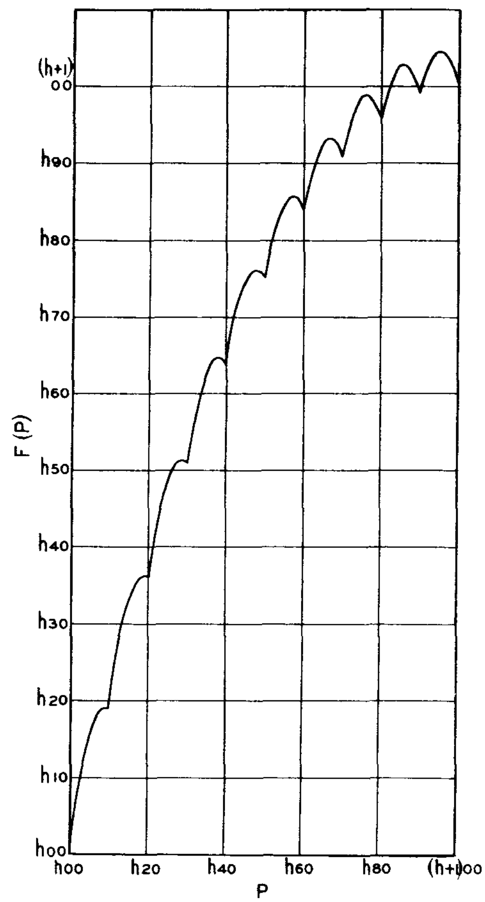


FIG. **2**.—GENERAL GRAPH OF P/F(P) FOR 1,000 OHM SULLIVAN SLIDE-WIRE.

An actual example will probably serve more readily than further explanation to illustrate the mode of conducting the test.

A full-earth cable fault on the Belfast-Portadown main trunk cable was localised between two surface boxes separated by a distance of 3,453 yards. A pair was broken down at random at the controlling joint box and " batteried-out " to the distant joint. The pair was then isolated and joined at both ends to the test sets. Adjustment of the slide-wires gave rise to the following test data :—

P_1 = 655
P_2 = 287
i_1 = 26.7 mA.
i_2 = 34.9 mA.

From the curve P/F (P) we obtain

$F(P_1)$ = 684.7
$F(P_2)$ = 302.3

Then since the test pair was 10 lb. conductor we have

r = 176 ohms/mile
l = 3453/1760 miles.
a = 15 ohms (each instrument).

By substitution,

x = 1659 yards from the control end.

This localised the earth into a 110 yards length which was opened and the fault proved therein.

Analysis of the Method.

The fundamental connections of the test are set out for analysis in Fig. **3**. The resistances of the slide-wires have been ignored and the slide-wires themselves replaced by E.M.Fs. e_1 and e_2.

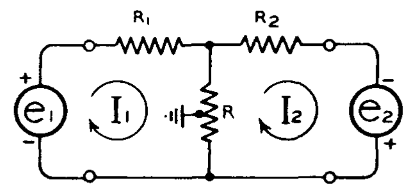


FIG. **3**.—CIRCULATION OF MAXWELL MESH CURRENTS.

The fault is assumed to be R_1 loop ohms from one end and R_2 loop ohms from the other and the fault resistance has any value R. Batteries e_1 and e_2 are applied at their respective ends and cause currents I_1 and I_2 to circulate the fault meshes.

Then, using Maxwell's current circulating conventions, we have

$$I_1 (R_1 + R) - I_2 R = e_1$$
$$-I_1 R + I_2 (R_2+R) = e_2$$

Solution by determinants leads to,

$$\Delta I_1 = \begin{vmatrix} e_1 & -R \\ e_2 & (R_2+R) \end{vmatrix}$$
$$= e_1 (R_2+R) + e_2 R.$$

$$\Delta I_2 = \begin{vmatrix} (R_1+R) & e_1 \\ -R & e_2 \end{vmatrix}$$
$$= e_2 (R_1+R) + e_1 R.$$

whence

$$\frac{I_1}{I_2} = \frac{e_1 R_2 + e_1 R + e_2 R}{e_2 R_1 + e_1 R + e_2 R}$$
$$= \frac{e_1 R_2 + R(e_1+e_2)}{e_2 R_1 + R(e_1+e_2)} \quad \ldots\ldots\ldots\ldots\ldots (1)$$

The two circulating currents I_1 and I_2, i.e., the currents measured by the line milliammeters A, are now equated.

Thence,

$$\frac{e_1}{e_2} = \frac{R_1}{R_2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

If terminal resistances Ra and Rb are included in the meshes the above expression becomes,

$$\frac{e_1}{e_2} = \frac{R_1 + Ra}{R_2 + Rb} \quad \ldots\ldots\ldots\ldots (3)$$

Suppose the meshes shown above represent a cable with an earth fault x miles from the controlling end battery e_1. If the loop resistance per mile of the faulty cable circuit is r ohms and the length of the circuit is l miles, then

$$R_1 = xr$$
$$R_2 = (l - x)r$$

whence from (3),

$$\frac{e_1}{e_2} = \frac{xr + Ra}{(l-x)r + Rb}$$

Separating x leads direct to,

$$x = \frac{e_1}{e_1+e_2} l + \frac{e_1 Rb - e_2 Ra}{r(e_1+e_2)} \quad \ldots\ldots\ldots\ldots (4)$$

This expression is fundamental to the constant current method of test and could be applied direct if it were possible to obtain batteries e_1 and e_2 with a zero or even constant internal resistance. As this is impracticable the voltages e_1 and e_2 must be applied to the cable ends through potentiometers whose internal resistance is accurately known.

Applying (4) to the double-ended slide-wire test it follows that,

$$e_1 = P_1 i_1 \text{ volts.}$$
and $$e_2 = P_2 i_2 \text{ volts.}$$

The 1,000 ohm Sullivan slide-wire is not a simple potentiometer but is constructed on the Kelvin-Varley principle. It follows therefore that the terminal resistance Ra is not P_1 but some function of P_1. The general value of F(P) can be readily obtained by measuring the resistance between S and the slider terminal for values of P ranging from 0 to 999 ohms. The graph of P/F(P) is symmetrical over each 100 range and Fig. **2** shows only one hundred range generalised in the form

$$h00 - (h+1)00$$

to cover the whole of P from 0 to 999.

It is now possible to take the application of the slide-wire test to equation (4) to completion. If the resistance of each line milliammeter is "a" ohms, then

$$Ra = [F(P_1) + a]$$
$$Rb = [F(P_2) + a]$$

whence

$$x = \frac{P_1 i_1}{P_1 i_1 + P_2 i_2} l + \frac{P_1 i_1 [F(P_2)+a] - P_2 i_2 [F(P_1)+a]}{r(P_1 i_1 + P_2 i_2)}$$

Effect of Variation of Fault Resistance.

The fundamental equation of the constant current test,

$$\frac{e_1}{e_2} = \frac{R_1}{R_2}$$

indicates that the resistance of the fault does not enter into the equation for localisation. To test this circuit property, a mesh with an artificial variable fault was built up to the form shown in Fig. **4**.

The line current was fixed at 20 milliamps and the fault resistance set at a series of different values. For each value of fault resistance a localisation was made and a set of typical results are set out below :—

Loop resistance = 2,500 ohms.
Loop resistance to fault = 1,700 ohms.

Test	Resistance of fault	Localisation	Per cent. error of loop
	ohms.	ohms	per cent.
1	10	1,680	0·80
2	100	1,684	0·64
3	1,200	1,686	0·56
4	4,000	1,680	0·80
5	8,000	1,682	0·72
6	16,000	1,692	0·32
7	26,000	1,684	0·64
8	35,000	1,676	0·96

With fault resistances above 40,000 ohms the localisation balance loses sensitivity and the percentage error increases progressively.

Effect of Varying the "Constant" Line Current.

Using the test mesh shown in Fig. **4**, the effect of using different line currents was investigated. With line currents of 2.0 milliamps it was found that the method begins to lose sensitivity with fault resistances

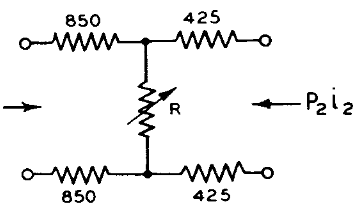


FIG. **4**.—TEST LOOP WITH VARIABLE FAULT RESISTANCE.

of 3,000-4,000 ohms ; with line currents of 10 milliamps the fault resistance can be extended to 10,000 ohms. It is apparent therefore that the range of the test, from the point of view of fault resistance, can be extended considerably by increasing the line current.

Polarisation Effects.

The effect of direct current testing on a wet cable is usually to set up polarisation. In the present test this is avoided as no current passes through the fault resistance when the steady state has been reached. Actually it is impossible to adjust the two end currents to exact equality but a very close approximation can be reached with care. In a series of tests with an artificial fault the out-of-balance current ($I_1 - I_2$) was measured and was rarely found to exceed 25 microamps.

During the period of balancing it is possible that currents of the order of 15-20 milliamps may traverse the fault and may set up polarisation. As soon as balance is attained, however, this polarisation will die away. It is for this reason that the line balance is maintained for a full five minutes before the final readings are taken.

Influence of Parasitic Currents.

The effect of parasitic currents on localisation accuracy was investigated on a test loop of 1,290 ohms with an artificial fault at a distance of 340 loop ohms. The artificial fault was built up by inserting a pair from a length of 28 pair, 10 lb. lead-covered cable, in circuit. The cable was punctured and placed in a trough of surface water. The ensuing fault was localised in the usual manner.

The 27 spare pairs were then commoned and connected, via a detector, to an earthed battery. The current flowing parasitically from the faulty spares to the sheath was adjusted to various values, for each of which a localisation was carried out. From these results the leakage currents appear to have little effect on the localisation accuracy. Some representative figures are shown below :—

Test	Parasitic current	Localisation	Per Cent. error of loop
	mA	ohms	per cent.
1	0·0	353·0	1·01
2	20·0	352·0	0·93
3	30·0	354·0	1·08
4	50·0	357·2	1·32
5	100·0	364·0	1·80

Accuracy of the Measuring Instruments.

Accuracy in localisation depends upon the accuracy of the measuring instruments. The two line milliammeters should be high grade instruments with a full scale deflection of 25 milliamps, with delicate pointers and preferably with mirror facings to avoid parallax. The two instruments should be calibrated by connecting them in series and passing a current of 20 milliamps through them. Both instruments should then be brought to read exactly 20.00 milliamps by means of the zero adjustment screw.

The two milliammeters used in the slide-wire circuits should be high grade instruments with a full scale deflection of 50 milliamps. When placed in series they should give exactly similar readings over the range 20-40 milliamps.

Accurate localisations have been made by using four Detectors No. 4, but success under these conditions calls for some experimental skill.

Possible Simplification of Method.

Certain simplification might be introduced into the method by using ordinary 1,000 ohm potentiometers instead of Sullivan slide-wires. If such instruments were arranged to have zero or negligible resistance in the slider arms, then the necessity for the P/F(P) curve would disappear, since

$$P = F(P)$$

for all values of P.

By equating the currents i_1 and i_2 in the potentiometers to some common value, say 40 milliamps, a further numerical simplification might be effected since the second term of the fault formula would be reduced to zero. Thus the expression for the fault becomes

$$x = \frac{P_1}{P_1+P_2} l$$

TELEGRAPH AND TELEPHONE PLANT IN THE UNITED KINGDOM.
TELEPHONES AND WIRE MILEAGES. THE PROPERTY OF AND MAINTAINED BY THE POST OFFICE IN EACH ENGINEERING DISTRICT AS AT 31ST MARCH, 1937.

Number of Telephones	Overhead Wire Mileages				Engineering District	Underground Mileages			
	Telegraphs	Trunk	Exchange*	Spare		Telegraphs	Trunk	Exchange†	Spare
1,041,399	378	3,360	54,405	7,572	London	36,712	298,556	4,111,289	73,838
129,785	1,718	12,445	54,749	10,044	S. Eastern	6,467	125,365	390,247	51,193
149,980	2,522	30,649	101,974	8,403	S. Western	25,995	86,826	319,437	100,942
107,772	3,372	34,260	89,109	16,769	Eastern	16,281	113,587	208,908	64,698
124,531	3,532	26,726	68,126	22,871	N. Midland	6,333	202,864	263,008	114,816
139,717	1,920	20,177	82,748	17,346	S. Midland	10,994	181,593	389,430	79,457
74,320	1,217	17,158	59,252	11,116	S. Wales	6,986	80,724	153,761	52,913
185,614	2,420	22,811	85,237	21,684	N. Wales	11,490	187,720	514,928	95,565
224,250	989	4,113	35,042	9,755	S. Lancs	9,684	159,057	740,831	56,447
93,481	801	6,203	35,401	18,759	N. Western	7,146	122,493	270,676	61,134
36,519	2,945	11,452	17,717	1,302	N. Ireland	411	9,009	92,464	20,077
261,328	5,040	33,591	90,993	25,502	N.E. Region	16,571	242,397	704,364	152,565
238,663	6,455	43,910	102,384	23,056	Scot. Reg.	13,653	217,338	498,686	109,215
2,807,359	33,309	266,855	877,137	194,179	Totals	168,723	2,027,529	8,658,029	1,032,860
2,747,246	34,897	280,543	858,542	180,802	Totals as at 31 Dec., 1936	163,028	1,965,606	8,596,338	979,986

* Includes low gauge spare wires (i.e. 40 lb. in open routes and 20 lb. or less in aerial cables).
† Includes all spare wires in local underground cables.

Waterloo Bridge—Alteration to Post Office Plant

H. WHENMOUTH

In the April issue of this Journal the work carried out at the north end of the temporary bridge was described. In this article the author outlines the subsequent work at the south side.

General.

THE plans for the proposed new bridge necessitated the clearance of the extremity of the temporary steel structure from the line of the Waterloo Road approach. The bridge contractors undertook to slew the last span of the temporary bridge approximately **34** feet eastward to a position shown in Fig. **1**.

The movement of **34** feet was too large to permit the use of slack cable as employed at the north end of the bridge, and it was decided to construct a skeleton steel structure to bridge the gap between the last pier of the bridge and the river bank, and by this method to ensure that the 17 cables diverted from the old route would be entirely free from damage or interruption, which might have occurred during the slewing of the bridge span if a less permanent solution had been adopted.

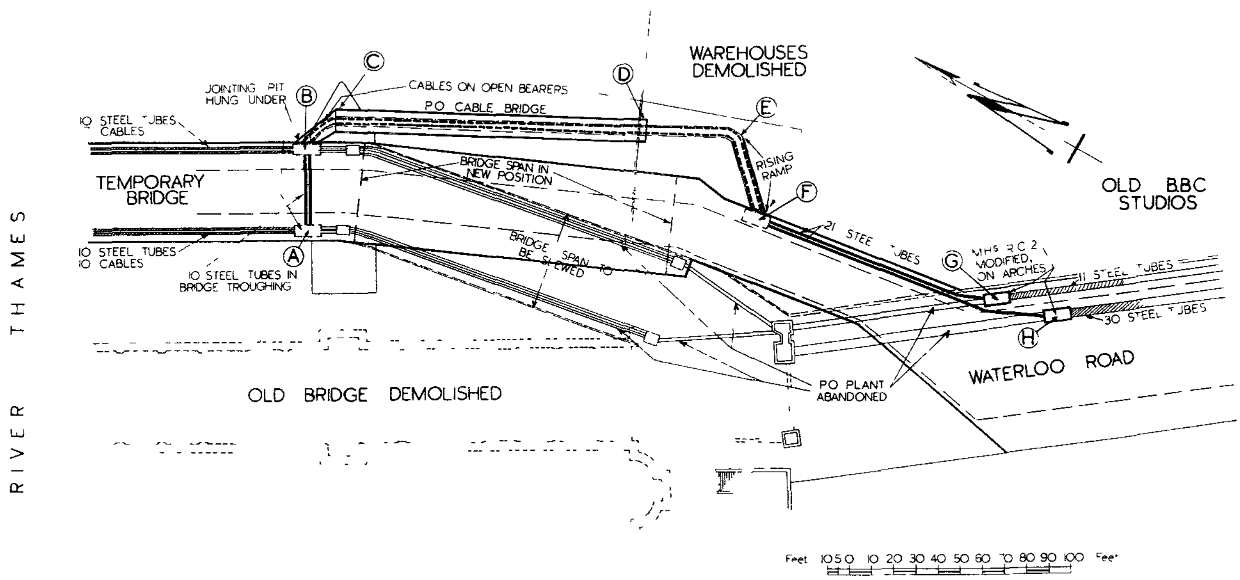


FIG. 1.—PLAN OF THE SOUTH END OF WATERLOO BRIDGE.

Route Construction.

It will be seen from Fig. **1** that ten cables existed under the west footway, and seven cables under the east footway of the temporary road bridge. Hanging jointing pits 12 ft. by 5 ft. by 4 ft. were constructed from the underneath side of the bridge at A and B, and connected by ten steel pipes laid in the steel troughing of the bridge structure. The box B was left open on the east side to allow cables to be drawn in from the end of the specially constructed cable bridge.

The minimum span between the last bridge pier and the river bank was 135 feet, and a single span Warren type bridge, C to D, was constructed under contract by Sir William Arrol & Co., Ltd., the contractors for the demolition of the old bridge.

The steel cable bridge has a gangway 3 feet wide throughout its length, and Fig. **2** shows a cross-section of the truss and disposition of the cable bearers capable of holding ten cables on both sides of the gangway. The cable run was continued to E by cable bearers of a type similar to those described above, fitted to 12-in. square baulks of timber.

From the point E, the route rose sharply on a steel ramp (Fig. **3**) 31 ft. 6 in. long, to a platform at F, constructed under the footway of the new roadway built to meet the slewed position of the bridge, and from this point the cables were led away in a nest of 21 steel pipes, supported on iron brackets, to their corresponding routes in new manholes at G and H.

Cabling.

The total lengths between A and H, and B and G were 162 yards and 135 yards respectively. It was obviously preferable to avoid the construction of intermediate joints on the cables, but owing to the nature of the work and the bridge construction in course of execution, it appeared in the first instance that such a course might have to be followed. The difficulty was surmounted, however, by hoisting the cable drum by crane on to the partially completed bridge-end at the manhole cover entry on the platform at F and cabling through the hole, down the ramp, along the platform and steel bridge (Fig. **4**), and fleeting through the pipes at B and A. The remaining cable was then taken from the drums in the form of

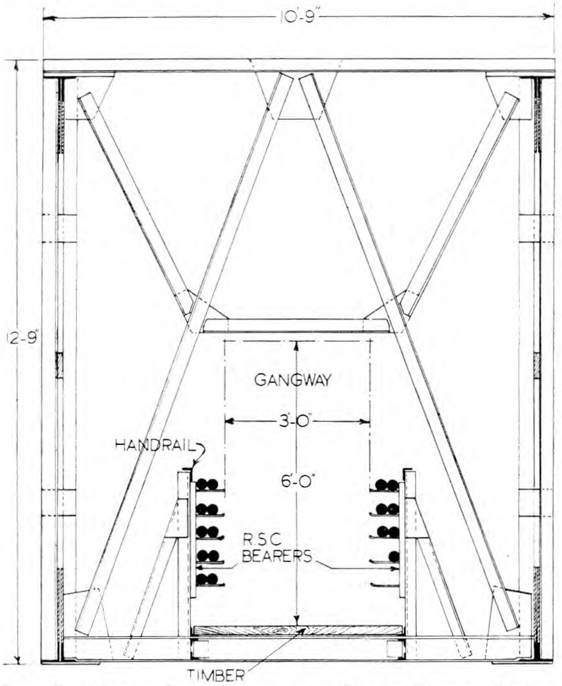


FIG. **2**.—CROSS SECTION OF THE CABLE BRIDGE TRUSS.

a loop down to the lower staging until the end was free from the drum. This was then fleeted through the steel pipe to G and H.

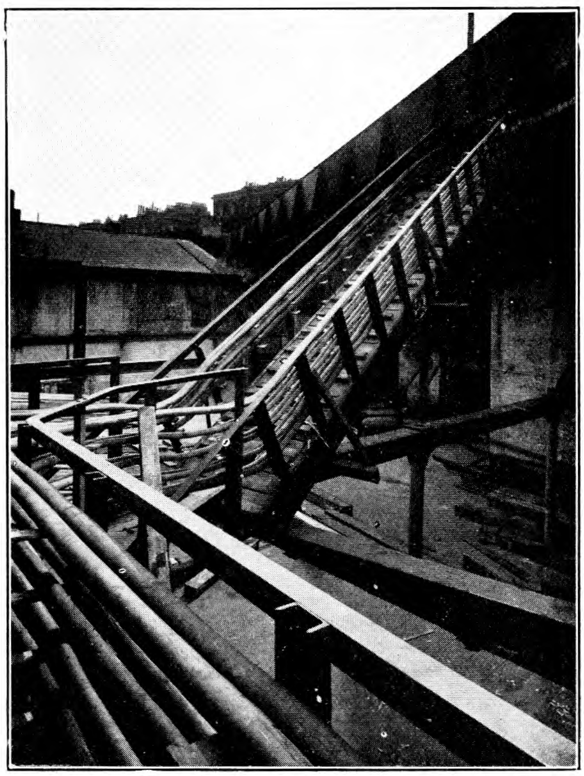


FIG. **3**.—STEEL CABLE RAMP.

The stripping of the steel pipes from the existing cables at A, B, G and H was again carried out without incident by means of the Skilsaw electrically driven cutting machine, as described in the April issue.

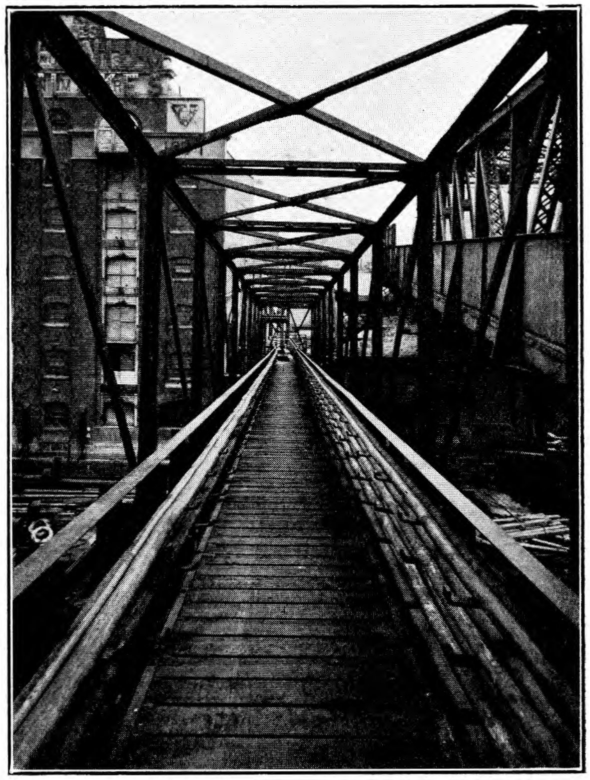


FIG. **4**.—WARREN TYPE STEEL CABLE BRIDGE.

Jointing.

Careful thought had to be given to the jointing arrangements in order that cables in the new manholes should be arranged around the walls of the manholes to conform with standard practice. In order to avoid an unsightly crossover, a small scale model was constructed and the position of each cable allocated to its appropriate cable bearer and pipe.

The transfer of the circuits from the old to the new cables was then carried out without interruption, special arrangements being made by means of clips and flex wire to give continuous service and avoid breaking the circuit even momentarily.

The end of the new cable was next set up in the orthodox manner, a spare cable pair being allocated on the new cable for a speaking circuit between change-over points.

Conclusion.

On Sunday, April 11th, the work of slewing the 1,000-ton bridge span was completed, the work occupying two hours.

The work of transferring the Department's plant has presented many problems, but each has been overcome. The whole operations have been of a most interesting character and the team work displayed by the Department's staff cannot be commended too highly.

Forth Bridge Cables

B. DAVIES, A.M.I.E.E.

The work of installing entirely new telecommunication cables across the Forth Bridge has just been completed. Cables on this bridge are subject to vibration, corrosion and the effects of expansion and contraction of the bridge. A review is given of the trouble encountered with the earlier cables and the methods adopted to minimise these troubles with the new installation are described.

Introduction.

ON March the 4th of this year the Forth Bridge was 47 years old. On this date, in the year 1890, the last of about 8 million rivets used in its erection was driven in by the late King Edward VII. In an age when improvements and inventions follow one another in quick succession, the wonders of yesterday become the commonplace of to-day, and this is particularly true in railway construction, but some things defy the passing years and among them is the railway bridge which spans the Firth of Forth.

The Forth Bridge (Fig. **1**) is probably the most famous bridge in the world. It is certainly the most familiar. During the summer months it attracts a constant stream of visitors from home and abroad, and views of the three giant cantilevers with their intricate maze of steel lattice work have been reproduced in innumerable settings. The bridge would have been a vastly different looking structure had it not been for the disaster which overtook the Tay Bridge. In 1879 the Tay Bridge of that time collapsed during a terrific gale, and a few years previous to this a proposal to bridge the Forth was under consideration. The Engineer who had built the first Tay Bridge was engaged on a design for a vast suspension bridge somewhat similar to the Clifton Bridge with two spans each of about 1,600 feet in length, the towers of which were to be 600 feet high. The disaster to the Tay Bridge showed what terrific wind force could be experienced in Eastern Scotland, and although the project to span the Forth was shelved for a time the disadvantage which the east coast route suffered through the absence of direct rail communication between London and the northern centres of Scotland, together with the acute competition of the west coast route via Carlisle and Stirling, caused the idea to be revived and new designs were prepared for the present cantilever structure. Had the original design been persevered with the bridge would have undoubtedly collapsed sooner or later as the designer had only allowed for a wind pressure of about twelve pounds per square foot. The gale that wrecked the Tay Bridge reached thirty pounds per square foot and with this knowledge the present Forth Bridge was designed to withstand a wind pressure of almost double this figure.

A few weeks before the official opening of the bridge a violent gale struck the Forth and the wind reached an even greater force than the gale which destroyed the Tay Bridge. It is said that the inhabitants of Queensferry, not unmindful of the disaster a few years before, were afraid to look out on the morning following the storm for fear they should look out upon a wreck. But the bridge stood firm and through all the years this wonder of engineering skill has withstood the stress and strain of heavy traffic, wind and storm, without showing the slightest sign of weakness. Perhaps the most remarkable feature of all is the fact that when the bridge was designed locomotives and tenders weighing less than 80 tons weight were in use, yet to-day the bridge carries the "Earl Marischal" and her sisters weighing 165 tons with correspondingly heavier rolling stock. Although the bridge is sufficiently strong to withstand a tornado it is very susceptible to corrosion which is enhanced by reason of its constant exposure to sea air. To guard against this, painters are employed constantly on the bridge and it is estimated that twenty tons of paint are used annually.

The bridge consists of two great spans of 1,710 feet long and two smaller spans. In addition, there are approach viaducts at either end. Overall, the bridge is about a mile and a half in length, but so beautifully balanced are its proportions that it does not look anything approaching this length. The height to the top of the cantilevers is 360 feet above high

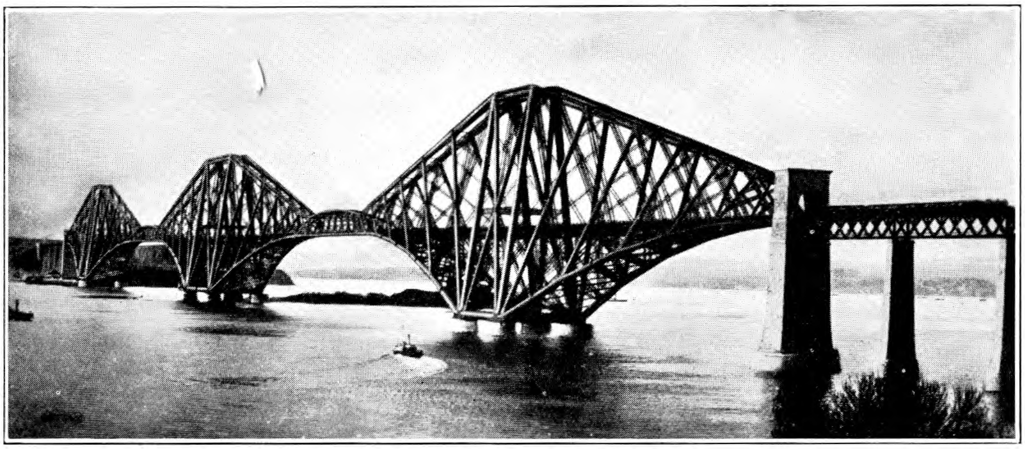


FIG. 1.—THE FORTH BRIDGE.

water mark. The railway track is 130 feet above the water. The foundations of the three cantilevers are secured soundly to the sea bed, one near the Queensferry shore, one near the Fife shore and the central one on the island of Inchgarvie. At each of these sites there are four piers and from the centre of each pier rises a steel tube twelve feet in diameter leaning inwards, each pair being connected by a horizontal tube of the same diameter. Additional strength is provided by means of other tubes radiating in all directions and further strength is imparted to the structure by an intricate system of transverse bracing. Looking through the bridge from one end to the other this transverse bracing suggests a maze of steelwork, yet looking broadside on from the Ferry Steamer "Queen Margaret," the bridge seems to be a particularly frail affair. Except at the ends, where the shore cantilever overhang reaches out to the approach viaduct, the overhang is insufficient to bring the arms together and the cantilevers have to support between them a girder span of approximately 350 feet weighing over 800 tons. These two girder spans are fixed to the cantilever at one end only, the other end resting on rollers.

The Early Cables.

The Forth Bridge was opened for traffic in 1890 and a few years later the first Post Office cable was laid across the bridge. This was a lead covered, paper core cable and it was placed in the 6-foot way between the up and down tracks, slack being provided at the expansion points. This cable gave continuous trouble due to fractures of the sheath and in 1909 it was substituted by a lead covered P.C.M.T. 34 pr. 70 lb. armoured cable. From the jointing chamber at South Queensferry the cable was taken up the stone pillar a distance of about 50 feet and then underneath the south approach for a distance of 550 yards to the first cantilever. Up the face of the stone pillar the cable was cleated to a wooden back board and enclosed in a wooden casing. Under the south approach it was suspended from the steel girders by steel strand and rawhide slings. Along the bridge itself the cable was merely laid on the footway on the east side of the bridge, no casing or troughing being provided. From the north end of the bridge to the jointing chamber at North Queensferry the cable descended the 130 feet pillar in a wooden casing similar to that provided at the south end. This cable, or at least the section on the bridge itself, was working until a few weeks ago. This cable gave satisfactory service for two or three years but in 1912 low insulation developed and an investigation revealed several fractures of the lead sheathing. These fractures were traced to the effects of expansion and contraction at the points where the cantilevers adjoin the fixed portion of the bridge at the approaches, and also to the effects of the movement of the rolling portions of the girder spans. Vibration was also a contributing factor but to a lesser degree. It was anticipated that trouble was likely to occur from the effects of expansion and movement, and at the junctions of the girder spans and also at the junctions with the approach viaducts the cable was provided with large loops or bights to take up the effects of expansion. These methods did not prove

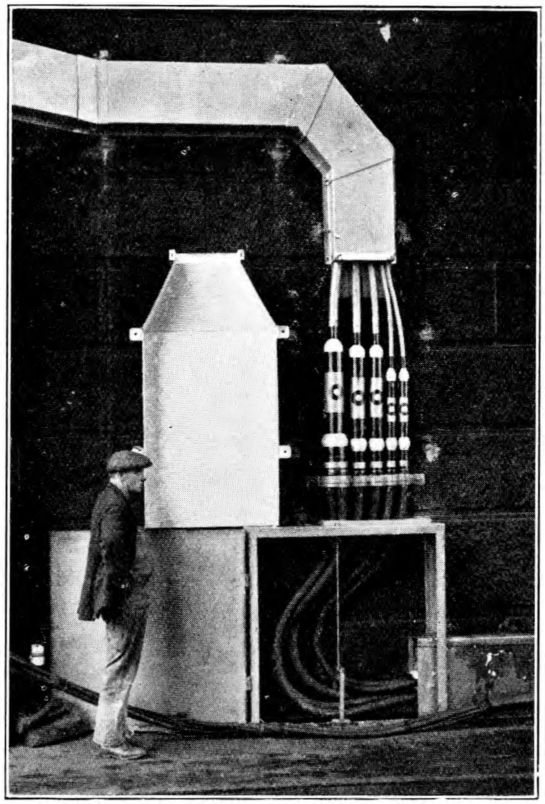


FIG. 2.—EXPANSION CHAMBER, SOUTH PIER.

satisfactory and the above-mentioned strains caused fractures in the cable sheath at various points along the bridge. To overcome the difficulty the bights were abandoned and at each expansion point short lengths of G.P. cable with lead covered plugs were introduced into the main cable, the G.P. cable being free to take up any movement. To reduce the effects of vibration and to protect the cable generally (the sheath having shown signs of disintegration) a wooden troughing was constructed and laid on the footway, the cable placed in it, and the whole filled with compound throughout the length of the lead covered cable to within a few feet of the joints with the G.P. plugs. This work was carried out in 1914 and although faults have since that time occurred the service given by this cable has, on the whole, been satisfactory.

After a life of about 20 years the wooden casing became due for renewal. By the beginning of 1936 its condition was beyond repair. It had been partially dislodged by constant vibration due to traffic, and burnt through in places by sparks from passing locomotives. In fact, in 1927 all communication to the north via the Forth Bridge cables was stopped due to casing and cables being completely burned out.

The New Troughing.

Since the original cable was provided in 1897, several additional cables have been laid in the casing and early in 1936, when the new Edinburgh-Aberdeen

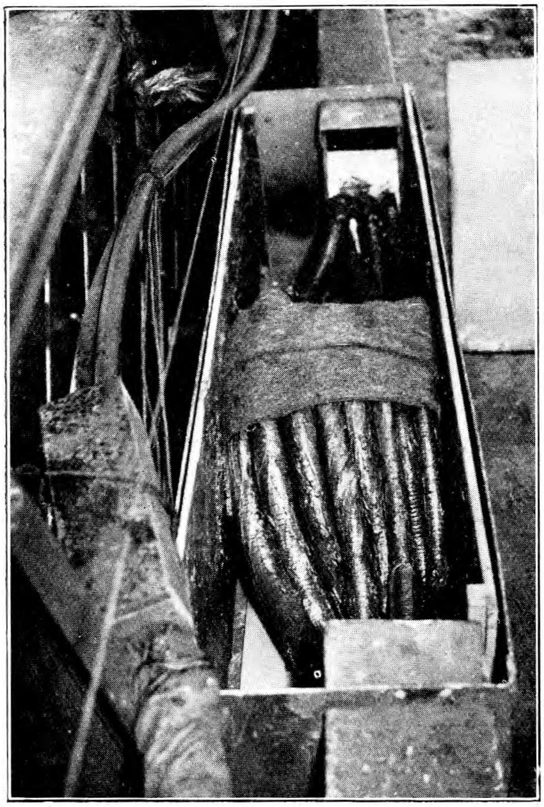


Fig. 3.—Intermediate Expansion Chamber.

carrier cable was decided upon, it became necessary to review the whole question of accommodating the new and existing cables on the bridge. It was decided to construct a new casing and, in view of the experience gained from the use of wood with its attendant dangers, particularly the risk of fire, it was decided to build the new casing of pressed steel. This decision was influenced to some extent by the insistence of the Railway Company that the overall dimensions of the new troughing should not exceed those of the existing casing, the space available on the footway being limited. The footway is only four feet wide and certain of the Railway Company's appliances have been designed specially to make the fullest use of the space available and any increase in the overall dimensions of the casing would render these appliances inoperative. A specification was prepared accordingly for a new steel troughing together with suitable steel chambers to act as expansion points. The specification provided for the troughing to be made of $\frac{3}{16}$ inch pressed steel, galvanised, with a hinged lid. The troughing was designed to be manufactured in twenty feet lengths, these to be electrically welded together on the bridge. The overall dimensions of the cable casing proper are $9\frac{3}{8}$ inches high by 7 inches wide. The joints between the individual twenty feet lengths are butt welded electrically, intermediate binding straps being provided and the whole resting on one inch hard wood blocks. The expansion chambers naturally exceed these dimensions considerably, the two at the approach ends (Fig. **2**) being four feet high by four feet long and twelve inches deep. At the intermediate expansion points the chambers are six feet six inches long, one foot eight inches wide and one foot ten inches high. The laying of the casing was commenced in August and completed early in November.

The principal difficulties experienced in the maintenance of the cables on the Forth Bridge have already been mentioned and the arrangements to overcome them have been stated. Although these arrangements have proved fairly successful it must be admitted that maintenance costs on the bridge have been high and it was decided before laying the new cables to do everything possible to reduce maintenance work to an absolute minimum.

Cabling Arrangements

When the renewal of the wooden casing was first envisaged it was thought possible to sling the existing cables temporarily from the handrail of the bridge during the laying of the new troughing and finally to reinstate them in the new troughing. The Railway Company were unable to agree to this proposal as such an arrangement would prove an obstruction to the travelling bosuns' chairs which the Company use for painters engaged upon the bridge. In addition, the Department itself had some misgivings as to the manner in which the old cables would stand up to the removal from the protective compound, temporary slinging for a period of 2 or 3 months and final reinstatement in the new troughing. Thus a rather critical stage was reached as there was insufficient room to lay the new troughing alongside the old casing. There was only one solution. On the opposite side of the bridge, on the west footway, the Railway Company had a small wooden casing accommodating their own signalling cables. As these cables were of V.I.R. type it was thought that the Company might agree to sling the cables for a time, recover their own casing and thus provide a clear run on this footway for the Department's new steel troughing. In the event of the Company's agreeing to this proposal it was intended that the Post Office should lay new cables throughout the length of the bridge and the south approach and when the transfer of the circuits from the old to the new cables had been accomplished, to recover the old cables and casing on the east footway, thus providing a clear run on that footway for the reinstatement of the Railway Company's casing and cables. Thus, at the completion of the operations, the Post Office cables, which since their installation on the bridge have occupied the east footway, would occupy the west footway and the Railway Company's cables would be transferred from the west footway to the east footway. The Railway Company, after some discussion, agreed to the Department's proposals, and thus the way was cleared for the provision of entirely new plant across the bridge.

Expansion Joints.

As the use of expansion joints with flexible connections and the employment of compound had proved successful in the past it was decided that the new work should be carried out on these principles, but with improved methods in their application. The

FIG. 4.—FILLING THE TROUGH WITH COMPOUND.

new expansion chambers and their relative positions do not vary in any essential detail from the existing chambers, but it was considered that an improvement could be effected in making up the flexible connections. After consultation with the Standard Telephones & Cables, Ltd., with whom the contract for the cable work was placed, it was decided that the new connections should take the form of paper core tails covered by a thick rubber tubing and the whole encased in flexible steel tubing filled with compound and sealed at the ends (Fig. **3**). The use of a paper core cable for the flexible portion is somewhat of an innovation. In the preliminary stages, when the methods to be adopted were being discussed, it was intended to provide these flexible sections on more or less the existing lines and to make up a number of cab tyre leads in quad formation, but this idea was abandoned finally in favour of paper core cable encased in a thick rubber tube. The need for preserving uniformity of electrical characteristics throughout the cable was the main factor in arriving at the decision to use paper core cable in the make-up of the flexible tails. Even such slight lack of uniformity as might be caused by the insertion of a few feet of rubber insulated cable would probably prove a serious handicap to carrier working and might possibly result in the loss of one or two channels.

The New Cables.

The new cables have a lead antimony sheathing and each cable has been served with a double wrapping of hessian tape. At the bottom of the steel troughing a half inch layer of felt has been laid to reduce the effects of vibration and finally the whole troughing has been filled with compound (Fig. **4**). Other improvements have also been made. The ascents up the stone pillars of the bridge have been made by means of vertical steel suspension strands to which the cables have been secured at frequent intervals by special leather lined clamps (Fig. **5**). In view of the height involved this is expected to prove much more satisfactory than the method formerly in use, where the cables were cleated together in a wooden casing. The vertical suspension strands have been terminated on special new girders at the top of the pillars, and at the foot of the pillars on eye bolts set in concrete. For the 550 yard length under the south approach the cables have been suspended from new steel strands by means of elder suspenders. To prevent damage to the cable sheaths due to vibration at the point where the cables leave the steel suspension system under the south approach and reach the firm structure of the stone pillars, a special cable racking provided with a cork bedding has been fitted. This racking on the approach side is a fixture, being bolted to one of the girders supporting the steel suspending wire, but the racking has not been fixed to the stone work of the pier. At this point, the racking is capable of sliding on a special bracket attachment supporting the cables up the stone pillar. As an additional precaution between the points where the cables leave the steel suspension system under the approach and where they reach the fixed position on the stone pier each cable has been encased in a flexible steel tube filled with compound and sealed at the ends. By the adoption of these measures it is hoped to damp out any vibration

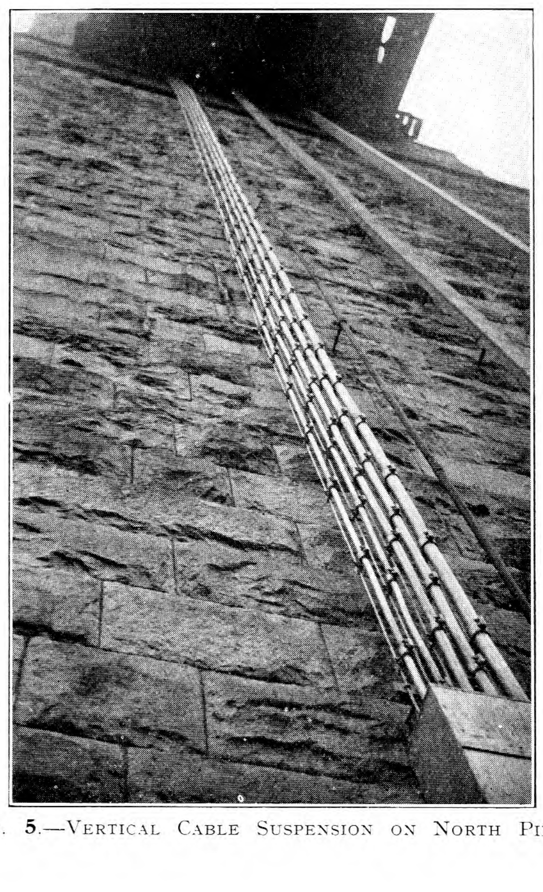


FIG. 5.—VERTICAL CABLE SUSPENSION ON NORTH PIER.

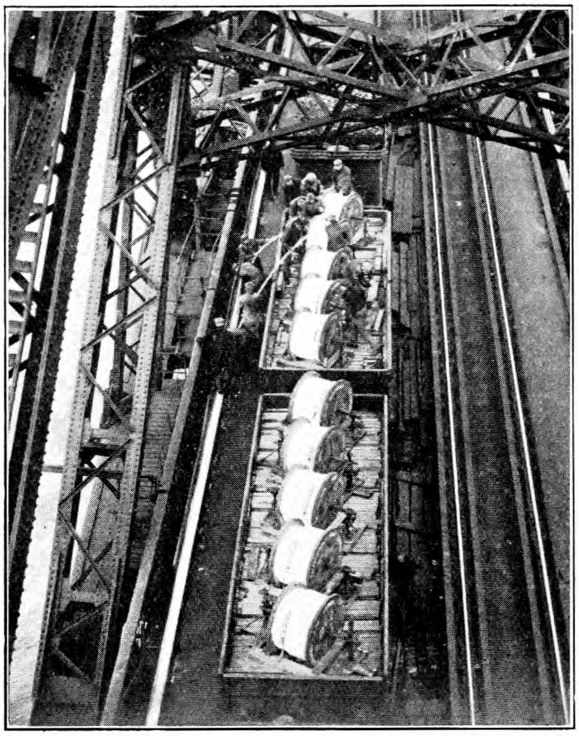


FIG. 6.—CABLE LAYING OPERATIONS.

set up on the suspension system before it reaches the rigid cable on the pier face.

Installation.

The laying of two new 24 pr. carrier cables and the replacing cables was commenced in December last. The drums were delivered to Dalmeny Station which adjoins the entrance to the south approach. For two or three successive Sundays single line working over the bridge was resorted to and the drums were loaded on to trucks, the trucks moved along the bridge and the cables paid off on to the footway and later lifted up and laid in the casing (Fig. **6**). The cables were then balanced and jointed and upon completion the compound was poured into the troughing. Arrangements were made to provide templates near the entrance to each expansion chamber to prevent the compound from reaching the flexible tails.

All the cables were laid, balanced, jointed and compounded by April. Acceptance tests were also made and the working circuits transferred to the renewal cables during the same month. By the time this article appears in print the old casing and cables will have been recovered and the Railway Company's plant installed in its place on the east footway of the bridge.

With the completion of the Forth Bridge carrier cables the new primary link with its 288 potential channels between Edinburgh and the north of Scotland will shortly be available for traffic. It is hoped that this link will be adequate to carry the long distance telephone traffic of Eastern Scotland for many years to come.

It is desired to acknowledge the valuable co-operation of the London & North Eastern Railway both before and during the operations. The Company's engineers have throughout given the Department and its contractors full benefit of their experience on the bridge.

Thanks are also due to Messrs. Standard Telephones & Cables Ltd., for the loan of the photographs reproduced in this article.

Long Trunk Development

Prior to 1934 the increase in long trunks was in the order of 2·5 per cent. per annum. In October, 1934, the first of the trunk rate reductions came into force and had an immediate effect on the provision. The following table gives the total number of long trunks working at quarterly periods from October, 1934, to October, 1936, together with the approximate totals at October, 1932, and October, 1933. It will be seen that the percentage increase October, 1934, to October, 1935, and that between October, 1935, and October, 1936, was of the order of 12 per cent.

Date ..	Oct., 1932	Oct., 1933	Oct., 1934	Jan., 1935	Apr., 1935	July, 1935	Oct., 1935	Jan., 1936	Apr., 1936	July, 1936	Oct., 1936
No. of Long Trunks ..	4,075	4,175	4,150	4,502	4,545	4,653	4,759	4,976	5,011	5,231	5,402

It is interesting to note that during the week preceding August Bank Holiday, 1936, over 60 new long trunks were brought into use; only a few years ago this would have represented a full year's development.

In December, 1935, two 3-channel carrier systems for use on overhead wires were brought into use between Bristol and Plymouth, and during 1936 a further 18 such systems were opened.

Carrier in Underground Cables.—At the end of 1935 and beginning of 1936 single-channel carrier systems were brought into use on the reconditioned East and West Coast cables. Similar single-channel carrier equipment is now being installed on the London-Liverpool, Newcastle-Glasgow cables.

Equipment providing one audio and four carrier channels is on order for several routes, and a 12-channel carrier scheme using separate cables for "go" and "return" channels, has been installed between Bristol and Plymouth.

Similar 12-channel systems are to be installed in the near future between

Edinburgh—Aberdeen.
Aberdeen—Inverness.
Edinburgh—Glasgow.
London—Leeds (via Cambridge).
London—Oxford—Gloucester.
Bristol—Gloucester—Birmingham.
London—Southampton—Portsmouth.
London—Salisbury—Exeter.

The Detection of Poisonous Gases in Underground Workings

C. E. RICHARDS, F.I.C.

The various gases which may gain access to underground workings are discussed, the methods of detecting carbon monoxide are indicated and a description given of the Palladium Chloride Gas Detector.

Introduction.

IN a recent article[1] some of the dangers of suffocating gases were described. In particular the article referred to the dangers due to the accumulation of carbon dioxide, and gave some details of a method of test which can readily be made by the use of an ordinary miners' type of safety lamp.

As anybody with experience of underground maintenance work will know, there are other gas dangers to be dealt with in manholes and cable tunnels besides the carbon dioxide hazard. Gases are commonly encountered which not only refuse to support life, but which also are highly inflammable, very poisonous, or both. The detection of these gases in time to prevent workmen from being overcome, or an explosion taking place, is a matter of some importance, and the provision of suitable means for detecting the varieties of poisonous or inflammable gas which may be encountered has been directly responsible for an enormous volume of research work all over the world. It is a many-sided problem, since not only have the different varieties of gas to be considered, but also the conditions under which tests must be made have a profound bearing on the methods which may be employed. In the laboratory, with the proper apparatus to hand, it is a comparatively simple matter to detect, and in most cases determine the amount of, any poisonous or inflammable gas in the atmosphere. Field conditions, however, impose many restrictions, and prohibit the use of many favourite laboratory methods.

It is the purpose of this article to discuss shortly the various gases which may gain access to underground workings in this country, and the detection of poisonous gases, in particular carbon monoxide.

Gases Found in Underground Workings.

The gases which are liable to be found in underground workings are :—

(1) *Carbon-dioxide.* This has already been dealt with and will not be further discussed.

(2) *Coal Gas.* First and foremost this is the gas to be guarded against when entering manholes or working at joint boxes. Coal gas is manufactured by the destructive distillation of coal, and in most neighbourhoods the old-fashioned " straight " coal gas obtained by this method, and which contained about 10 per cent. carbon monoxide, is diluted with one of the varieties of water gas (made by blowing steam over red hot coke : $H_2O + C \rightarrow CO + H_2$), so that the resultant mixture, although being of rather lower calorific value, contains almost double the quantity of carbon monoxide. The poisoning danger of coal gas lies principally in its carbon monoxide content, which on the average amounts to about 15 per cent. but which may reach 20 per cent. or more.

When coal gas of average composition is present in air in concentrations of between 6 per cent. and 29 per cent. the mixture is explosive. Air containing less than 6 per cent. will not ignite, and that with more than 29 per cent. will burn quietly.

(3) *Marsh Gas* or methane CH_4 is formed by the decomposition of organic matter in the absence of air. It is seldom encountered in underground workings in this country, though its presence is said to have been established in a few instances. It is not poisonous, but will not support life. It is inflammable and methane-air mixtures containing from 6-12 per cent. methane are explosive. Methane is the inflammable constituent of " fire-damp " found in coal mines, and also of the frequently reported but rarely met (in this country) " sewer gas."

(4) *Petrol Vapour* is an explosion danger which is on the increase and has been the cause of a number of explosions in sewers, since it seems impossible to dissuade the public from emptying waste petrol down the house drains. Petrol vapour has from time to time found its way into manholes and joint boxes, due usually to leakage from garage storage tanks. Petrol vapour, although not harmless to breathe, is not dangerous enough to necessitate testing for its presence in merely poisonous quantities. The explosive range of petrol is small, being only from 2 per cent. to 6 per cent. in air. Petrol vapour has a density about $2\frac{1}{2}$ times that of air, and would consequently show on an ordinary gas leak indicator as a " heavy gas."

(5) *Acetylene* C_2H_2 is a gas capable of causing extremely violent explosions when mixed with air. So far as is known, no explosions have occurred due to this gas in manholes, and as the use of acetylene lamps is likely to decrease, trouble from this source is not probable.

(6) *Bitumen Gas* is a rather broad term given to any gas which is formed when a power cable overheats and is formed by the slow distillation of the bitumen which is used for protective purposes. Bitumen gas is similar to coal gas in composition and its formation is frequently followed by an explosion due to the power cable failing and the arc igniting the gas. Bitumen gas should be treated with at least the same respect as coal gas, since it is similar both in poisonous nature and inflammability.

(7) *Hydrogen Sulphide* H_2S. This gas is not likely to be encountered in quantity, but it is extremely poisonous. The only probable source of hydrogen sulphide is manholes is fermentation following infiltration of sewage. In dilute mixture with air, this gas has a very foul smell, usually described as resembling rotten eggs, and for this reason it is not readily overlooked.

---

[1]*P.O.E.E.J.*, Vol. 28, p. 201.

Carbon Monoxide.

It has been stated above that the poisonous constituent of coal gas is carbon monoxide. This also applies to bitumen gas. Carbon monoxide is a colourless, odourless and insoluble gas having very nearly the same density as air. Its poisonous action is due to the fact that it will combine readily with hæmoglobin, the coloured blood constituent which normally carries oxygen from the lungs to the body tissues. As carbon monoxide takes the place of oxygen the blood is partially prevented from carrying oxygen to the body, and if the process goes far enough the man or animal dies from lack of oxygen. The extent to which the blood becomes contaminated with carbon monoxide depends in the long run on the relative mass influences of the oxygen and carbon monoxide present. At body temperature the affinity of blood for carbon monoxide is about 300 times its affinity for oxygen. Thus a person breathing air containing only 0.1 per cent. carbon monoxide would eventually have his blood 59 per cent. saturated with carbon monoxide. According to Hartridge, 58 per cent. saturation of the blood is sufficient to cause death. This result would, of course, only occur after prolonged exposure to the gas, but it must be realised that the concentration of carbon monoxide referred to is equivalent to less than 1 per cent. of coal gas.

Probably the greatest danger from carbon monoxide arises from the fact that one of its early effects is paralysis, and the victim may know quite well that he is being poisoned but not be able to move or shout to save himself.

Methods of Detecting Poisonous Gases.

In considering the methods to be adopted for detecting poisonous gases weight must be given to such points as these :—

(1) For which gases must regular tests be made ?
(2) What degree of sensitivity is required ?
(3) Under what conditions must the test be made ?
(4) Should the method be one requiring deliberate tests to be made from time to time, or should the apparatus be of the kind which will be operative the whole time a man is underground and give an alarm signal of some kind when gas is encountered ?

The answers to the above questions will vary between organisations undertaking different types of work, and so far as the Post Office Engineering Department is concerned have been as follows :—

(1) The only gas requiring deliberate routine tests is carbon monoxide. This is principally because of its widespread distribution.

(2) The detector must, of course, be capable of finding carbon monoxide when it is present in quantities well below the danger limit. It has been decided that if carbon monoxide is originally present in a manhole when opened for work to the extent of 0.1 per cent., nobody shall enter the manhole. If when first tested the manhole shows the presence of between 0.05 per cent. and 0.1 per cent. it may be considered safe for work for short periods only, and if less than 0.05 per cent. is present no further precautions need be taken.

(3) It must be possible to make tests fairly quickly and without entering manholes.

(4) Preferably the method should be of the automatic sentinel type. It will be noticed below that this type is not provided. The reason for this is that although automatic carbon monoxide detectors are known, they are all too complicated to be suitable for use by external staff.

Detection of Carbon Monoxide.

The occurrence, and some of the properties of this gas have been described above. The amount of carbon monoxide which can be tolerated by human beings for more than an hour or so is not much more than 0.05 per cent. This is equivalent to about 0.3 per cent. coal gas of average composition, and it will therefore be appreciated that somewhat refined methods must be used to detect the gas before it reaches a dangerous concentration.

Since the principal source of carbon monoxide is coal gas, it may be asked why the latter should not be detected by smell. There are several reasons for this, for instance :—

(1) The sensitivity of the olfactory organs varies considerably between individuals, and also many persons have particular idiosyncrasies. Normally it should be quite easy for the average person to detect 0.5 per cent. coal gas, but there are many people who could not smell that quantity. Again, it may be quite easy to detect a smell when first encountering it after being in fresh air, but if the gas causing the smell increases in concentration very slowly the nerves lose their sensitivity.

(2) Although coal gas is thought to have a distinctive smell, one's idea of that smell is generally obtained by smelling gas straight from the tap. Gas which has filtered through the ground for some distance and has collected in a damp manhole may have a very different smell, in which the musty smell of decaying vegetation may predominate. It is probably for this reason that so many cases of infiltration of coal gas are reported as being " sewer gas."

(3) The possibility of carbon monoxide from other sources than coal gas must not be overlooked, e.g., gas engine or petrol engine exhausts, which may contain 10-20 per cent. carbon monoxide.

A number of carbon monoxide detectors have been devised from time to time, but they mostly are variations on four chemical reactions :—

(1) Iodine pentoxide will react with carbon monoxide, giving iodine and carbon dioxide

$$I_2O_5 + 5\,CO \rightarrow I_2 + 5\,CO_2$$

As depicted, the reaction will only take place at fairly high temperatures, but if the iodine pentoxide is dissolved in fuming sulphuric acid, it will react at room temperature. It is in this form that the test is usually applied for field tests. The air to be tested is freed from substances which would interfere with the reaction, or give false indications, by filtering through absorbent charcoal, and is then passed through a glass tube containing a white porous material such as pumice or unglazed china soaked in a solution of iodine pentoxide in sulphuric acid. After a certain amount of gas has been passed through the indicator tube it is compared with a standard colour chart. The depth of the colour developed and the length of the stain is proportional to the amount of carbon monoxide in the sample.

(2) Carbon monoxide and oxygen will unite at ordinary temperatures in the presence of a suitable catalyst, and give carbon dioxide. In doing so a certain definite amount of heat is given off.

$$2\,CO + O \rightarrow 2\,CO_2 + 136 \text{ Calories}$$

Therefore, if air containing carbon monoxide, and free from interfering compounds, is passed over a suitable catalyst, the rise in temperature of the catalyst will be a measure of the amount of carbon monoxide present. Several catalysts are known which will cause this reaction to proceed at comparatively low temperatures, and the one generally chosen is "Hopcalite" which is a mixture of copper and manganese oxides prepared under controlled conditions. The apparatus necessary for carrying out this test is expensive, and the use of the method is practically limited to the testing of air conditions in tunnels carrying motor traffic, as it is easy to get a permanent record of the amount of carbon monoxide present. The Mersey Tunnel is equipped with this type of apparatus.

(3) Carbon monoxide will reduce ammoniacal solutions of silver salts, the darkening of the solution being proportional to the amount of carbon monoxide.

(4) Carbon monoxide will react with palladium chloride, reducing it to metallic palladium.

$$Pd\,Cl_2 + H_2O + CO \rightarrow CO_2 + Pd + 2\,HCl$$

This reaction is almost specific for carbon monoxide, and after consideration has been made the basis of the routine test for the presence of carbon monoxide.

The Palladium Chloride Gas Detector.

In order to make the use of the test as widespread as possible, and so reduce the chances of workmen entering dangerous places, it was necessary to design apparatus that was both robust and simple to operate.

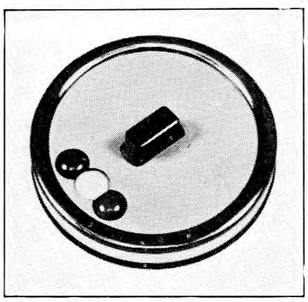


FIG. **1**.—THE PALLADIUM CHLORIDE INDICATOR FOR CARBON MONOXIDE.

The pattern finally adopted is shown in Fig. **1**. The component parts of the indicator are six. (Fig. **2**).

(1) The base, which contains
(2) A spongy rubber disc.
(3) A plain pressure plate which lies on the rubber.
(4) A top plate with coloured buttons.
(5) A clamping ring which screws on the base and holds the set together.
(6) Test papers (not shown).

About six spare test papers can be carried. When assembling the set for use, the reserve test papers are placed on the base, followed by the pressure plate; and one test paper is inserted between the pressure plate and the top plate. The whole assembly is then clamped moderately tightly by the clamping ring

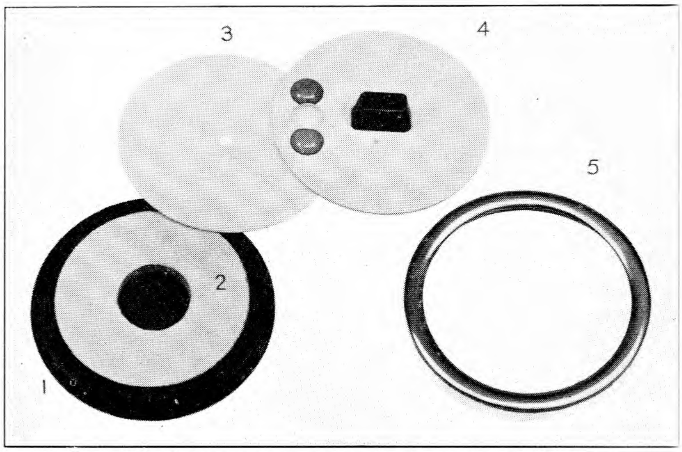


FIG. **2**.—COMPONENTS OF THE PALLADIUM CHLORIDE INDICATOR.

so that it is possible to rotate the top plate without turning the test paper. A small circle of white paper is visible through the hole in the top plate, between the coloured buttons.

The test paper used is ordinary good quality chemical filter paper, 7 cms. diameter. Pre-sensitised paper is not supplied as it has been found that this material tends to deteriorate on keeping. The active material is supplied separately in small phials, and consists of a 1 per cent. solution of palladium chloride in acetone and water. It is most important that none but the proper supply of this substance is used, as the solution must be made under carefully controlled conditions, any departure from which causes a change in sensitivity, and renders useless the colour scale provided. (It may perhaps be mentioned that one case has already occurred, in which, owing to the temporary shortage of supplies, a phial of solution was made by a local pharmacist. The liquid, although palladium chloride and of the right colour, would not detect carbon monoxide, as a large excess of acid had been used).

The test for carbon monoxide is conducted as follows:—

The test set is assembled as described above, and a drop of the active liquid is applied to the test paper. This is done by pressing the point of the inverted phial lightly on the centre of the circle of test paper visible through the hole in the top plate. Sufficient liquid should be applied, completely to cover the visible section and a little more. The sensitivity of the test is to some extent dependent upon the amount of liquid used. The ideal size of spot is one which eventually spreads to $\frac{3}{4}$ - 1 inch on the paper. With a little practice, spots of this size can be made no matter what amount of liquid is in the phial. The liquid of course flows more readily the smaller the amount remaining in the phial. The apparatus is now ready for immediate use, and must be used at once, while the paper is still fully wet. Any delay in exposing the paper to the atmosphere under test will reduce the sensitivity and render the colour scale invalid. The test is made by exposing the test paper to the air for just five minutes. When testing manholes before entering them the lid should be lifted partly off and the indicator lowered by a string, which may be tied to the handle. At the end of the five minutes the colour of the test paper is compared with that of the buttons at either side of the hole. The colour scheme of the top plate is :

(1) The top plate itself is the colour to be expected in the absence of any gas containing carbon monoxide.

(2) The lighter of the two buttons is the colour equivalent to 0.05 per cent. carbon monoxide, and provided that the test paper is not darker than this the atmosphere is safe for work.

(3) The darker of the two buttons is the colour equivalent to 0.1 per cent. carbon monoxide. If the colour of the test paper is intermediate between that of the two buttons it is safe to work for short periods, up to a maximum of two hours. Frequent tests (say once every half-hour) should be made to ensure that the atmosphere is not getting worse, and an occasional few minutes in fresh air is advisable. This can conveniently be at the time when the repeat tests are being made. In all probability repeat tests will show little or no carbon monoxide, since open manholes tend to clear themselves fairly quickly. If the colour of the disc is darker than that of the darker standard, work must be discontinued as the atmosphere has become dangerous. In these circumstances workmen who have been in the manhole should take plenty of fresh air. In no case should a manhole be entered when this test result has been obtained.

When a test has been made, the top plate can be turned to a fresh part of the test paper and thus leave the instrument ready for making a fresh test. About 8 or 10 tests can be made with one disc of paper, and each phial of palladium chloride solution contains enough liquid for about 70 or 80 tests.

It is most important that the liquid in the phials is not tampered with in any way, as the whole reliability of the test depends on this being exactly as specified.

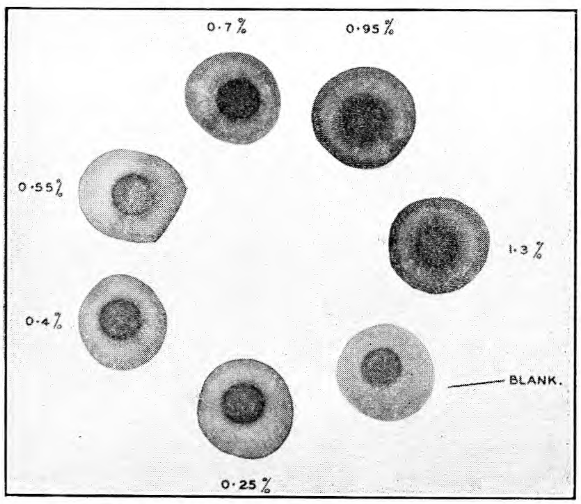


FIG. 3.—RELATIVE DARKENING OF INDICATOR IN AIR CONTAINING VARYING AMOUNTS OF COAL GAS.

If it is suspected that the liquid is not satisfactory, a blank test in the open air should be made, and unless the colour closely matches that of the top plate the phial should be scrapped, and a fresh one obtained. In Fig. 3 an attempt is made to show in black and white the relative darkening which is obtained in air containing varying amounts of carbon monoxide, which has been added in the form of coal gas containing 15 per cent. CO. The black and white result is not nearly so striking as when the actual specimens were viewed in colour, but should give some indication of the degree of darkening to be expected.

There are, of course, other gases which affect palladium chloride, and these may cause a positive result to be obtained when in fact the atmosphere is free from carbon monoxide. Since the purpose of this test is principally to protect the workman from entering a dangerous atmosphere, this is not considered a fault. The fact that any gas should be present which is capable of reacting with palladium chloride is one which calls for investigation. The only commonly occurring gases which have any pronounced effect on palladium chloride are hydrogen (over 5 per cent.), petrol vapour, ethylene (1 per cent.), acetylene and hydrogen sulphide (0.01 per cent.). The last of these is the only one which is likely to be confused with carbon monoxide, as the other gases turn the paper a warm brown rather than a dark grey. Sulphuretted hydrogen is itself so poisonous that it should be avoided as carefully as carbon monoxide.

The Palladium Chloride Gas Detector in Service.

Since the Palladium Chloride gas detector has been in general service one or two difficulties have been brought to light. Fortunately none of these is serious, but it may be useful to have them on record for reference. The first trouble which was experienced was that certain batches of active fluid did not keep well, and after a time could not be used. Investigation showed that there are two main sources of trouble with this liquid. (1) After a time the liquid is found to contain a black flocculent sediment which leaves dark blotches on the test paper, and which will readily settle in the tube. This is due to the use of unsuitable acetone in preparing the palladium chloride solution. A special method of refining the acetone must be used to ensure freedom from this trouble. (2) A more common fault has been due to the liquid remaining bright and clear for a short time—long enough to be tested and approved—and then slowly darkening, though depositing no sediment. This type of liquid gives a stain much darker than that of the face plate even in fresh air, and it is not possible to detect small amounts of carbon monoxide satisfactorily. This darkening of the liquid has been found to be due to the dissolution of some material, probably sulphur, from the rubber inserts in the phial caps. In the present supplies of phials care is taken to remove this interfering material from the rubber before use.

If, in spite of the precautions which are now taken in the preparation and packing of the palladium chloride solution, peculiar results are obtained when making tests, a test made in fresh air should show whether the liquid is in good condition or not. If the stain on the paper, when viewed after five minutes, is approximately the same colour as the face plate of the instrument, and the phial of solution is not much more than six months old, the liquid is almost certain to be in good condition. No cases are at present known in which liquid less than six months old has deteriorated, and most liquid aged up to two years and more has (when of good colour) been found satisfactory. It is too early yet to be certain of the life of palladium chloride solution, but there seems no reason why it should be less than 12 months.

Another point which has been raised is whether the indicator will give equally satisfactory results whether the carbon monoxide is present as coal gas or in any other mixture, e.g. exhaust fumes from a petrol engine. Tests have shown that under all practically conceivable circumstances the results are dependable.

The use of the indicator in stagnant air and in air currents has also been mentioned. The indicator was designed for use in practically stagnant air, such as is found in manholes, and the actual calibrations were made in gas mixtures moving past the instrument at about six inches per minute. Tests in absolutely stagnant gas, and in rapidly moving gas mixtures have, however, shown that no appreciable difference can be detected between the amounts of darkening.

There is one peculiar limitation of the indicator which has come to light, and probably explains why many demonstrations made in gas ovens and over gas burners have failed. This is that when the concentration of coal gas (containing 15 per cent. CO) reaches about 40 per cent, darkening of the palladium chloride does not occur, the colour changing from buff to a yellowish green. This appears to be due to the formation of an additive compound between carbon monoxide and palladium chloride, which compound does not break down under the conditions of test to give metallic palladium. This effect does not become apparent until very high gas concentrations are reached and is not considered a practical difficulty.

The Second International Congress of the International Association for Testing Materials

AT its first congress held in Zurich in September, 1931, the International Association for Testing Materials accepted the invitation from the British Committee to hold the next congress in Great Britain, and as a result, the congress took place in London from April 19th-24th, 1937.

The object of these meetings is to obtain international co-operation in the study of materials and their testing, and to provide facilities for the exchange of views, experience and knowledge with regard to all matters connected with this subject. The London Congress was regarded as being of considerable scientific and industrial importance, particularly in view of the length of time which had elapsed since the study and testing of materials was last reviewed on an international basis.

From the point of view of the British organising committee, the result must have been very gratifying, as some seven hundred or more delegates of all nationalities were present at the plenary opening session held in the Grand Hall of the Institute of Civil Engineers, where the visitors were welcomed by the President, Sir W. Bragg, O.M., K.B.E., Pres.R.S. After reading a message of welcome from His Royal Highness the Duke of Kent, K.G., the president, in a happy speech, said he extended a hearty British handshake to all present and hoped that, whatever views they held concerning this country, they would return with pleasant memories acquired during their brief sojourn in this country—" our country is yours " he said—" yours for a brief period; science knows no frontiers and we hope that you will return with a higher appreciation of our country than you held before," and with this stirring message the congress settled down to work.

The subjects selected for discussion were divided into four groups and among the 150 papers presented were one or two which made notable contributions to the existing state of knowledge, and many served as authoritative summaries of the position reached to date.

The following members of the Engineering Department attended the sittings, Capt. B. S. Cohen, Dr. W. G. Radley and Messrs. C. E. Richards and E. V. Walker, Research Branch, and Messrs. F. O. Barralet, A. B. Eason, G. F. Tanner and J. Jupp, Test and Inspection Branch.

The papers were read in English, French or German, and as advance copies were available in most cases, the author usually contented himself with giving a few amplifying remarks and replying to any questions; for the latter purpose an interpreter was available.

These advance copies of the papers are available to anyone who feels sufficiently interested, on application to the Department's representatives. A Congress Book will be issued later which will contain, in addition to the papers presented, an account of the proceedings and articles by each of the four group presidents, in which attention will be directed to the principal additions to knowledge recorded in the papers and discussions.

In addition to the technical sessions of the Congress, numerous visits were arranged to places of scientific and industrial interest, as well as many social functions, including an official reception by H.M. Government.

G. F. T.

The Coronation : Telecommunication Arrangements

The Coronation of Their Majesties King George VI and Queen Elizabeth threw a heavy load on Post Office Engineers. Some idea of the work involved will be gathered from this article in which a brief summary of the lines and equipment provided by the Post Office is given.

THE world wide interest in the coronation of King George VI gave the Post Office engineers a considerable amount of work in providing the communication facilities required both for the months of preparation and on Coronation Day itself.

This was the first time in history that a coronation was broadcast all over the world. B.B.C. commentators were placed at points along the procession route and in the Abbey itself, and microphones were installed in the Abbey to enable the complete ceremony to be broadcast. This broadcast was effected from all transmitters of the B.B.C. including the Empire short wave transmitter. In addition, the Post Office radio links to the Empire and to North and South America were used to relay the programme and twelve continental countries sent their own commentators so that the countries concerned could hear a description of the events in their own language. This involved a considerable network of wires which was set up by the Post Office in conjunction with the colonial and foreign administrations concerned. The procession was also televised from Hyde Park Corner, this being the first outside television broadcast in this country. A fitting climax to the Coronation Day broadcasting was the Homage Programme and His Majesty's address to the Empire.

The programme provided by the B.B.C is well known and is generally acknowledged to be the finest commentary ever attempted, but it is not perhaps appreciated that the Post Office engineers have so much to do in connection with an event of this sort and an attempt is made here to give a brief survey of the work involved. Detail is not possible in the space available, since on any one of the items which are scheduled below a long account could be written.

Apart from the broadcasting there were facilities required by a number of public administrations, hotels, etc. Preparations for the provision of these facilities were commenced as far back as August, 1936.

For some time prior to the Coronation large numbers of empire and foreign visitors were arriving in this country and this meant increased telephone facilities, particularly with the dominions and other countries. As each visitor from abroad landed at Liverpool or Southampton, he was presented with a booklet outlining the services of the Post Office which were at his disposal and inviting him to inspect Faraday Building, the Post Office Railway, and the Central Telegraph Office.

On Coronation Day press representatives from all over the world were present in London and facilities were provided whereby they could telephone or telegraph both news and pictures to their offices.

Some of the pictures that were telegraphed by the Daily Sketch to their provincial offices are shown as a matter of interest and we are pleased to record our thanks for permission to reproduce these pictures.

Special Services

The majority of the special services were confined to central London and involved private communication networks, the more important of which are mentioned below.

The Abbey.

In Westminster Abbey a most complicated network of circuits was provided for all the various organisations taking part in the arrangements prior to and during the Abbey ceremony.

Firstly, a $\frac{5 + 20}{25}$ switchboard was fitted up with 4 extensions to St. James's Palace, one to Office of Works' Headquarters and one to the House of Commons, with 20 internal extensions to various control points in the Abbey, including first-aid posts and police points.

A 20-line multiphone switchboard was provided for the Chief Gold Staff Officer, with extensions to various parts of the Abbey, for use in connection with the showing of members of the congregation to their seats. There were also 6 point-to-point circuits for general use.

An intricate system of microphone wiring, covering 47 microphone points, was wired in the Abbey for the B.B.C., the greater part being overhead and connected to the control switchboard provided by the B.B.C. The whole of the wiring in the Abbey had to be carefully concealed as far as possible, and, in all, approximately 12 miles of small cable were provided.

Press.

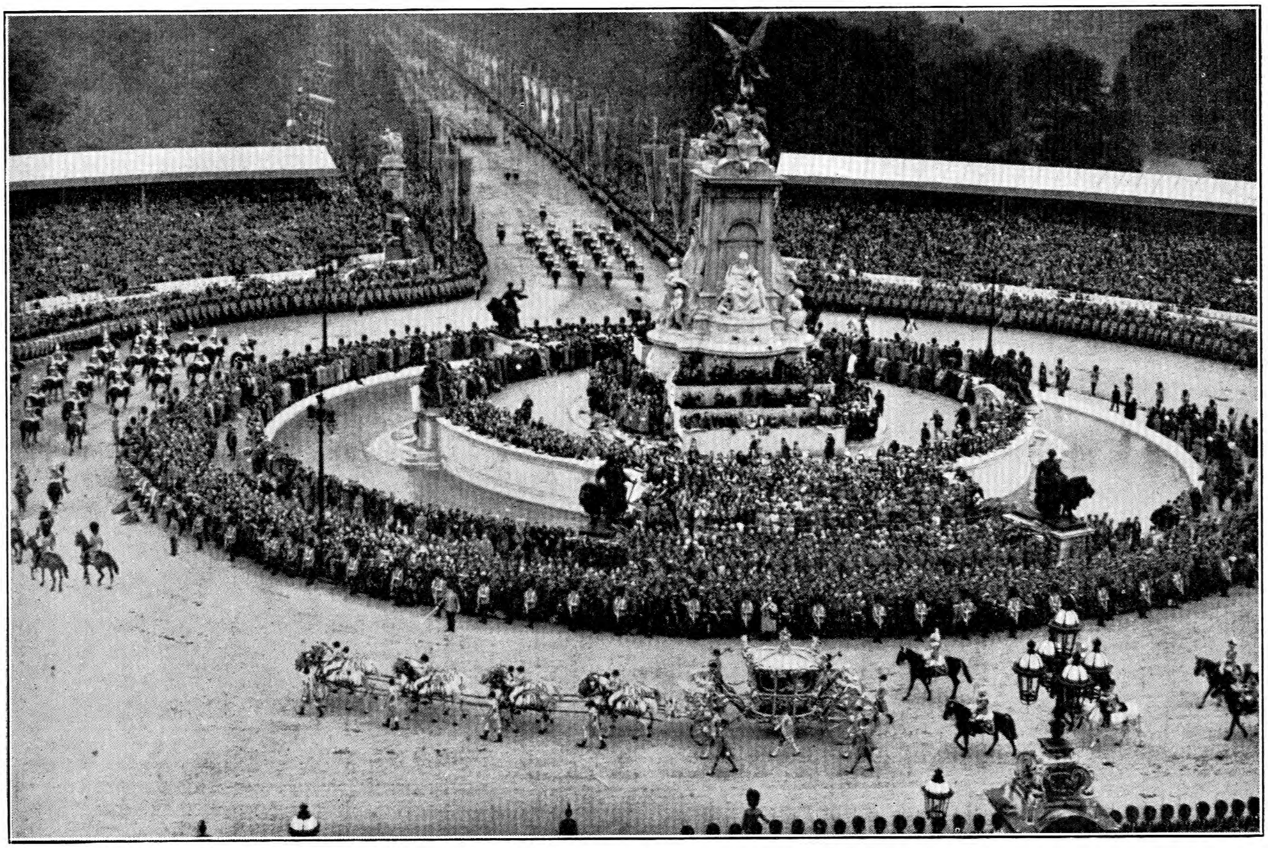
Several hundred members of the press were present in London both at points of vantage along the route and in the Abbey. Along the route arrangements had to be made to enable the representatives to report to their offices as quickly as possible either by telephone or messenger. One newspaper anticipating difficulty in transporting pictures across central London during the actual time of the Coronation was provided with a circuit for picture transmission from an office in Whitehall to the newspaper office in Fleet Street.

Three hundred pressmen were present in Westminster Abbey for the Coronation, and the journalists represented not only London and the provincial agencies and newspapers, but colonial, dominion and foreign papers. Arrangements were made to provide in the grounds of the Abbey cabinets to accommodate call offices, exchange lines, private wires, and a telegraph circuit to the Central Telegraph Office.

Metropolitan Police.

Special facilities were provided for the Metropolitan Police in order to enable them to carry out their work of controlling vehicular and pedestrian traffic. The main items were in connection with (a) the information room at Scotland Yard, (b) the control of traffic and car parks, (c) police stations and (d) crowd control at high barrier points.

(*a*) *Information Room at Scotland Yard.* The existing information room is served telephonically



by means of extensions off the main Scotland Yard switchboard, but for the period of the Coronation the extensions were converted to exchange lines and increased to 10 in number, and four switchboard positions were added. Further, an additional information room of ten positions was established with six exchange lines and two extensions from the main switchboard.

(*b*) *Control of Traffic and Car Parks.* Wherever possible private subscribers' lines and kiosks were used, and some 34 existing kiosks were reserved for the exclusive use of the police in connection with this control. In addition seven temporary exchange lines were provided.

(*c*) *Police Stations.* Additional apparatus and temporary exchange lines and extensions were provided for certain police stations in central London.

(*d*) *High Barrier Points.* High barriers were erected at strategic points to assist the police in the control of crowds, and the Post Office was asked to provide 21 temporary exchange lines to these barriers, 18 of which were terminated in small boxes and three in cabinets.

B.B.C.

In order that the B.B.C. could carry out their successful commentary on the procession and Coronation, the Post Office provided an extensive network of broadcasting and control lines. These linked up Broadcasting House with the various commentators' huts on the route and with the Abbey itself. The accompanying diagram, showing part of the network, gives some idea of the amount of work involved. Where there were more than four circuits between any two points an alternative route was followed by some of the circuits.

Further, the Abbey ceremony was broadcast to all stands along the procession route. Loud speakers were provided by H.M. Office of Works. This entailed another network of lines to be provided by the Post Office.

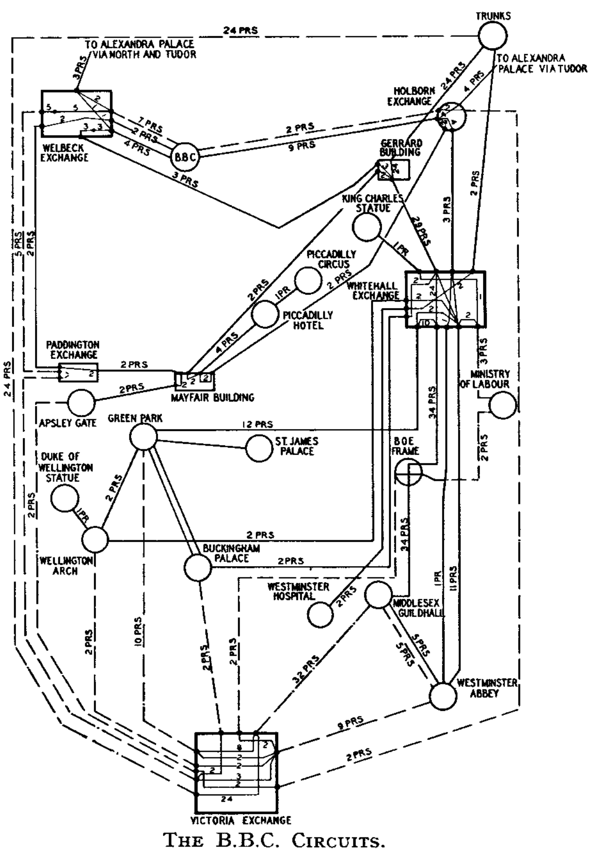
Television.

The first outside television broadcast carried out in this country was made from Hyde Park Corner on Coronation Day. The B.B.C. television camera van at Apsley Gate, Hyde Park, was connected to the broadcast transmitter at the Alexandra Palace by some nine miles of screened pair cable with repeaters and equalisers at Broadcasting house and at Alexandra Palace.

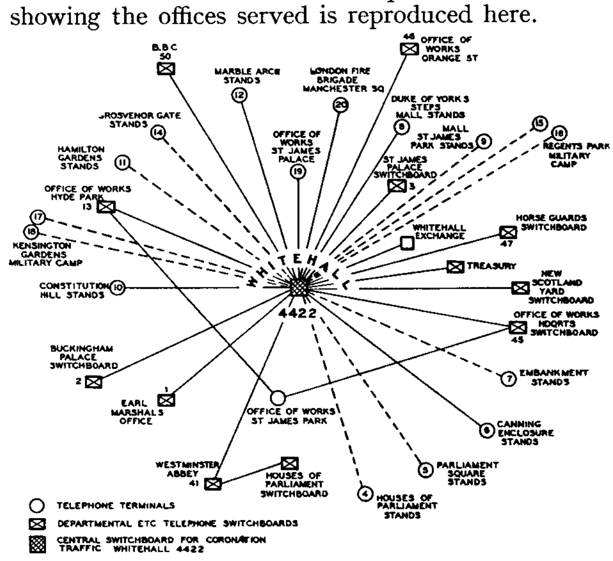
Hitherto, the television cameras have only been operated in the immediate vicinity of the broadcast transmitter, but no appreciable deterioration in picture quality was introduced by transmission of the signals over the cable link. The cable employed in this broadcast constitutes part of the network laid for the purpose of linking up places of interest with the television transmitter. Suitably located tapping points are being made to allow the mobile television equipment to be connected to the cable during a broadcast. In addition, a co-axial cable was provided between Broadcasting House and Alexandra Palace and special frequency conversion equipment provided to act as a standby to the balanced cable. This was not used owing to the satisfactory operation of the balanced system.

H.M. Office of Works.

In order to provide direct communication between the many officials responsible for making the arrangements for the Coronation and also to facilitate communication on Coronation Day itself, a switchboard which was known as "Coronation Exchange" was installed in St. James's Palace. It was connected by six exchange lines to Whitehall exchange and given a number on that exchange (Whitehall 4422). A special directory for the coronation exchange was issued in the form of a folder. A portion of the folder showing the offices served is reproduced here.



The B.B.C. Circuits.



Offices Served by the Coronation Exchange.

This switchboard was brought into service on February 8th, and staffed by the Post Office.

Earl Marshal's Office.

A temporary switchboard was provided as early as October, 1936 at the Earl Marshal's office at Buckingham Gate. This installation was equipped with 10 exchange lines (Victoria 6880), 15 external extensions and direct lines to Buckingham Palace, St. James's Palace and the Earl Marshal's residence in St. James's Square. In addition a house telephone system consisting of 12 stations was provided in February, 1937.

Transport.

A number of additional exchange lines and telephone extensions was provided to assist the London Passenger Transport Board.

Fire Brigade.

Owing to the fact that the Coronation procession surrounded two large areas which did not contain a Fire Station, special temporary Fire Stations were set up on Coronation Day at five points, and the usual telephone and alarm facilities were provided. Further the Fire Brigade made arrangements to patrol the stands and had men stationed at 15 Fire Alarm points during the day.

Military Circuits.

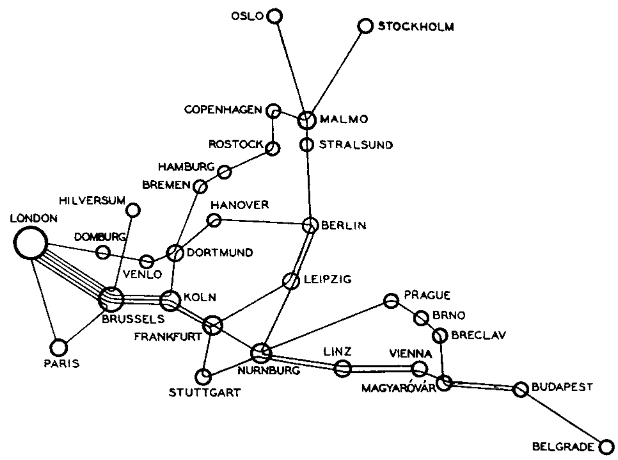
Over 40 camps were established in Kensington Gardens alone, and these and others in various parks in London, were provided with telephone facilities. In addition, lines were provided to the Tower of London, St. James's Park, and Windsor, from Westminster Abbey, so that the gun salutes at these places should synchronize with the act of crowning in the Coronation Ceremony. Lines were also provided for controlling the procession.

Miscellaneous.

Since August, 1936, a systematic canvass was made of those subscribers who were likely to want additional telephone facilities. Orders were obtained for 174 exchange lines, 10 temporary lines, 103 extensions, 2 private wires and 177 hand microphones. These subscribers included hotels, clubs, large stores, and railway, shipping and tourist companies.

Continental Broadcast Transmissions.

Requests were received from twelve Continental Broadcast organisations for music circuit facilities from this country for the purpose of relaying commentaries on the Coronation in their respective national languages. In addition, these organisations desired to take the whole of the Coronation Ceremony from Westminster Abbey. There existed only three music channels between this country and the continent and steps were taken to increase this number to cope with the additional broadcast traffic. Three additional music circuits were set up between London and Brussels and one between London and Paris and, with the close co-operation of the Dutch Technical Service, a music circuit was provided between London, Aldeburgh and Domburg to Venlo and was connected with a German music circuit at Dortmund.



Continental Circuits for Relaying the Broadcast.

The accompanying diagram shows the main circuits that were provided. This network involved 50,000 miles of wire and 150 amplifiers. From a study of the diagram, which was circulated to all the Technical Administrations concerned, it will be seen that only seven broadcasts were possible at any one time. This was the maximum required simultaneously, and consequently a detailed programme had to be prepared in advance so that the necessary changes in the network could be made in order to provide the correct countries with the commentary they required in their own language. On the Saturday before the Coronation a complete test over the entire network was carried out from the Middlesex Guildhall to all the countries concerned.

Complete alternative arrangements were also made so that in case of breakdown emergency wires could be used, and co-operation between the British Post Office, and the Belgian, Dutch and German Administrations was made by telephone. The transmission of all the commentaries and the Abbey service was carried out without a hitch, and recourse to the emergency arrangements was not necessary. The success of this broadcast was in no small measure due to the excellent co-operation received from the foreign administrations concerned.

Picture Services.

The Post Office picture service employed continuously two direct lines from London to Berlin, one for the actual transmissions and the other as an order wire circuit. Arrangements were made so that Berlin could relay the transmissions simultaneously to any of eleven receiving centres. Traffic to centres other than those connected to this system was transmitted over the normal channels and special arrangements were made to reduce the delay.

In addition to the official services, a number of newspapers and press agencies made "picture" calls, using selected trunks to agencies on the continent, so that at one time there were eleven pictures being transmitted simultaneously to the continent.

At the same time the normal picture service between the London and provincial offices of a number of newspapers was augmented by the provision of additional private wires so that coronation pictures could be reproduced in northern towns with the minimum delay.

Overseas Broadcasting.

The week Sunday May 9th to Saturday May 15th was by far the busiest in the Department's experience from the overseas broadcasting point of view. Countries all over the world took a keen interest both in the preparations and in the Coronation Day itself. In addition to the relay of the Abbey Service over the trunk network to the continent, more than sixty direct broadcast transmissions were made during the week, ranging over all hours of the day, starting with Australia at 5.30 a.m. British " Summer " Time and usually finishing with America (U.S.A.), who are "five hours back," round about 4 a.m.

Coronation Day itself, from the broadcast point of view, was naturally the peak. Australia, Canada, South Africa, Argentine, Brazil, Japan and the extensive networks of the National and Columbia Systems of the U.S.A., all heard the stirring Abbey ceremony and the interesting commentaries of the procession.

The climax was reached with the Homage Programme and his Majesty's address to the Empire on the evening of the 12th May. We at home heard loyal messages from New Zealand, Australia, India, Canada, South Africa and Bermuda, all coming via the Post Office Station at Baldock. Then followed the speech of the newly crowned Monarch which the world heard via Rugby Radio Station.

Effect on Normal Telephone Services.

Owing to a large number of visitors residing outside London additional trunks were provided to 20 towns in the Home Counties. Publicity had been given to the Alarm Call service whereby those who intended to view the procession could be wakened by telephone call in the early hours of the morning and an organisation was prepared in order to cope with the anticipated heavy demand for this service.

Additional equipment and staff were obtained for all London exchanges and it was arranged for a proportion of the staff at the central exchanges to sleep on the premises on Coronation eve.

Additional junctions and exchange equipment were provided to meet the anticipated increase in local traffic, particularly that from the vicinity of the procession after the proceedings were completed. As far as junctions were concerned in the London Area some 10,000 junctions were added between October 1936 and April 1937 to meet the increase of traffic expected, not only from the Coronation, but also from the reductions in local call tariffs which came into force in October, 1936. The telephone exchange equipment contractors supplied at short notice 3,200 switches, 1,600 banks and 300 relay-sets in the various exchanges affected.

Crossing of the Atlantic by Messrs. Merrill and Lambie.

Additional to the work contingent on the main event of the week, came rush service in connection with the double crossing of the Atlantic by Messrs. Merrill and Lambie.

First, their arrival at Croydon found the Department's engineers hastily furnishing lines and microphone equipment. This was actually done within two hours, and so, on the tarmac at the Croydon air-port, the flyers were telling the folks back home in U.S.A. just how it was done. Then again on Thursday, 13th, between 2.30 p.m. and 6.30 p.m., line preparations were made between London and Ainsdale Beach, Southport ; engineers and equipment were rushed by 'plane from London and the great American public heard their two flying heroes just before they took off and the roar of the engines as their machines tore along the sands on its happy return.

Coronation Naval Review.

An occasion like the Spithead Review causes a very considerable increase in the number of calls from Portsmouth and Southampton, in addition to which facilities must be provided for news and picture services. To carry the extra load 16 through circuits were cut at Portsmouth and Southampton and used to provide new trunks to London.

Conclusion.

The fact that the whole of the proceedings were carried out according to plan and without a hitch speaks well for the thoroughness with which the Post Office arrangements were planned and executed and great credit is due to the staff concerned. The Journal is indebted for the information contained in this article to the London Engineering District, and to the various Headquarters Branches which have collaborated in its preparation.

Protection of Post Office Circuits in Northern Ireland

D. C. BLAIR, A.M.I.E.E.

The author describes the use of gas discharge tubes to protect communication lines paralleled by high voltage power lines.

Introduction.

IN a previous article[1] in the Journal reference was made to the use of gas discharge tubes to protect communication lines when they are paralleled by high voltage power lines. This article gives a brief description of the salient features of the installation of these tubes on the Post Office circuits in Northern Ireland.

It is well known that where parallelism exists between high voltage power lines and communication lines there is a possibility of dangerous voltages being induced in the communication circuits, should an earth fault occur on the power system. The magnitude of the induced voltage is directly proportional to the fault current, and by limiting this current it is possible to ensure that the induced voltage will not reach a dangerous value. The maximum value of induced voltage permitted by the Department is 300 volts.

Practically all power systems in Great Britain are operated with the neutral point of the supply connected with earth, and it is common practice to limit the earth fault current by introducing resistance in this earth connection. There are, however, certain practical limitations to this method, e.g. the difficulties attending the setting of protective gear on the power system increase as the fault current is reduced; also when a resistance is fitted in the neutral connection with earth the potential of the neutral point can rise to a considerable value above earth potential under fault conditions. This rise of potential is chiefly dependent upon the value of the resistance, and since the insulation of high voltage plant is often graded, the value of the maximum permissible resistance is limited by the insulation provided at the neutral point.

The Electricity Board for Northern Ireland operates an extensive system of 33 kV overhead lines which in a number of instances are near and closely parallel to Post Office circuits. The system is supplied from the Belfast Corporation's Harbour Power Station. Originally the Board took its supply at 6.6 kV which was stepped up through its own transformers to 33 kV for supply to line, and the fault current was limited to the value required for the protection of the Post Office lines by means of a resistance connected in the neutral connection with earth on these transformers. To meet the growing load the Belfast Corporation has installed additional turbo-alternator sets having built-in transformers which, in effect, generate at 33 kV, the neutral point of the output of these sets being solidly earthed. In the meantime the load demand on the Board's system was increasing more rapidly than had been anticipated and the Board was obliged to make arrangements to take a larger load from the Harbour Power Station, and this could be obtained only by taking supply direct at 33 kV from the new plant. Under this arrangement the transformers in which the limiting resistance was fitted would be thrown out of service, and since the neutral of the 33 kV sets was solidly earthed it was necessary to consider alternative measures of protecting the Department's plant. It was clear that any measures applicable to the power plant or to the communication circuits would involve a considerable expenditure, and before embarking on any scheme of protection, tests were carried out to determine whether the calculated values of induced voltage would be experienced in practice. The tests proved that the measured and calculated values were in close agreement. The map in Fig. 1 shows the power lines concerned and the Post Office routes affected, while the curves in Fig. 2 show the measured values of induced volts per ampere of fault current for the three routes most seriously paralleled.

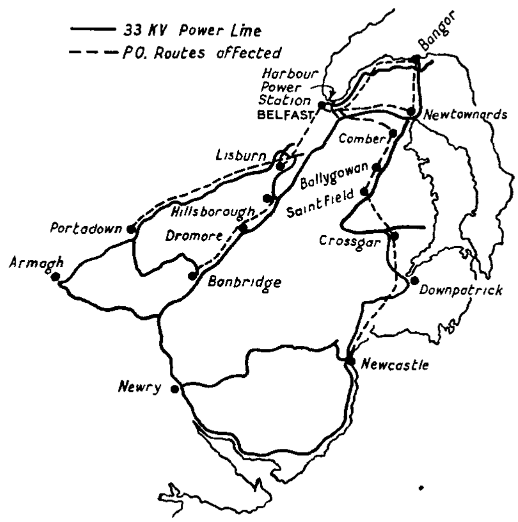


FIG. 1.—MAP SHOWING LINES AFFECTED.

Particulars of the Board's system appear in Appendix I.

Protective Measures.

The first protective measure to be considered was that of inserting a resistance in the neutral connection with earth at Harbour Power Station. The value of such a resistance would of course need to be sufficiently high to give the required limitation of fault current on the most severe parallelism, viz. Belfast-Newcastle route. By calculation (see Appendix I) it was found that the resistance would need to be several hundred ohms, which, so far as the Belfast Corporation was concerned, was quite impracticable both on account of insulation of its plant and the redesign of protective gear which would be entailed.

[1] *P.O.E.E.J.* Vol. 30, p. 1.

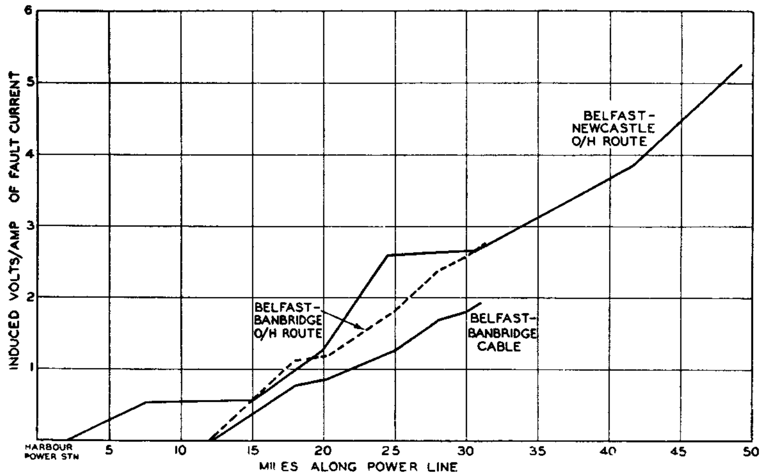


FIG. 2.—INDUCED VOLTAGE PER AMPERE OF FAULT CURRENT.

The second alternative was for the Northern Ireland Electricity Board to install a bank of 1 : 1 transformers and insert a resistance at the neutral of the secondary winding. This scheme, however, would have involved enormous initial expenditure and a considerable annual expenditure in the form of power losses in the transformers.

In view of the high cost of ensuring complete protection by measures on the power system, it was decided to investigate the possibilities of adopting additional protection on the Department's circuits. The first step in the investigation of this aspect was to determine the number of circuits which would be exposed to an induced voltage in excess of 300 volts. As already mentioned, the induced voltage is directly proportional to the fault current, which itself varies with the distance of the fault from the power station. The decay of the fault current with increase in distance from the power station is shown in curve I of Fig. **3**, and it will be seen that for faults near Belfast the current will be extremely heavy. On this account it was found that quite short parallelisms with local circuits in Belfast would call for additional protection which in view of the large number of circuits involved would have been extremely difficult and costly to provide. It was found that by inserting a 10 ohm resistance in the neutral connection with earth at Harbour Power Station the fault current would be considerably reduced for faults over the first few miles of line (see curve II, Fig. **3**) and would give adequate protection on all the routes affected, except those to Newcastle and Banbridge. The Belfast Corporation agreed to fit a resistance of this value, and it has been installed accordingly.

For the protection of the circuits on the Belfast-Banbridge and Belfast-Newcastle routes two methods were possible:

(1) The circuits could be split into sections by means of transformers such that the voltage induced in each section would not exceed 300 volts. This method had already been employed on previous similar instances of serious parallelism.

(2) The circuits could be fitted with a form of gas discharge tube which, while normally non-conducting, would flash over at a predetermined voltage and thus, in effect, earth the line.

The majority of the circuits on these routes are provided with dialling facilities to Belfast, and consequently method 1 would have necessitated reversion to generator signalling or the provision of voice frequency dialling ; these remedies were neither desirable nor practicable in the time available. In these circumstances it was decided to adopt method 2, which although never before employed in this country, has, it is believed, been tried experimentally on the Continent and in America.

CONSIDERATIONS GOVERNING THE CHARACTERISTICS OF THE TUBES.

Acoustic Shock.

The induced voltage appears longitudinally in each wire of a pair, so that if an earth connection is provided on one wire the voltage in the other wire will tend to discharge through this earth via the terminal equipment ; such a discharge is liable to result in severe acoustic shock. This condition would be obtained if single gas-discharge tubes were fitted to each line, since from a manufacturing point of view it is impracticable to adjust the gas pressure sufficiently critically to ensure that each tube will have precisely the same operating voltage. Simultaneous discharge from each line can, however, be more closely approached by using three-electrode tubes, i.e. tubes having two line and one common earth electrode in the same envelope, and this type was therefore adopted (see Fig. **4**).

Striking Voltage.

From a protection point of view it would be desirable to make the striking voltage as low as possible, but a limit is set by the voltages normally employed on the telephone circuits, and to avoid operation of the tubes on ringing voltages, a striking voltage of 150 volts was adopted.

Current Carrying Capacity.

The current which any tube will be called upon to carry will depend upon :—

(1) The resistances of the earthing systems to which the tubes are connected.

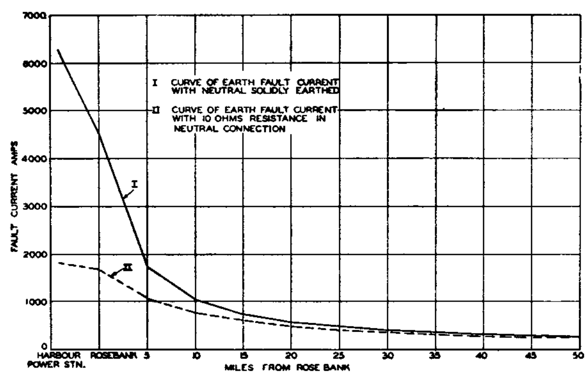


FIG. 3.—EARTH FAULT CURRENT CURVES.

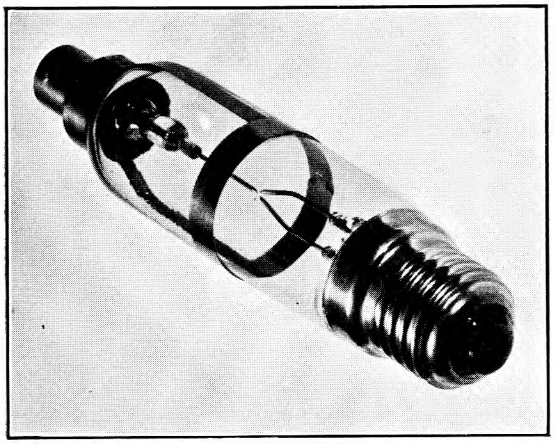


FIG. 4.—GAS DISCHARGE TUBE.

(2) The value of the induced voltage.

(3) The resistance of the telephone line.

Factors 2 and 3 depend again upon the position of he fault, and as already illustrated, can readily be alculated. As will be shown later, factor 1 exerts most important influence upon the current which ach tube will discharge, but for obvious reasons it vas indeterminate during the initial stages of the vork. It was estimated, however, that currents as igh as 10 amperes could be expected in each of the pen wires, and of 1 ampere in the underground ines. It has subsequently been proved that the esistance of the earthing systems are rather higher han was anticipated, and consequently the current arrying capacity of the tubes for the overhead ircuits could have been somewhat less than that pecified.

The tubes will of course operate only for the time hat the fault persists on the power line; this time is ontrolled by the setting of the discriminating protecive gear on the power system and, depending upon he position of the fault, can be a matter of several econds. In testing the tubes a period of 10 seconds vas taken ; each tube for the overhead circuits was equired to withstand without failure five 10-second lischarges of 20 amperes (10 amperes through each ine electrode), time being allowed for cooling between ach test. The tubes for the underground circuits were subjected to similar tests except that the discharge current was 2 amperes, i.e. 1 ampere through each line electrode.

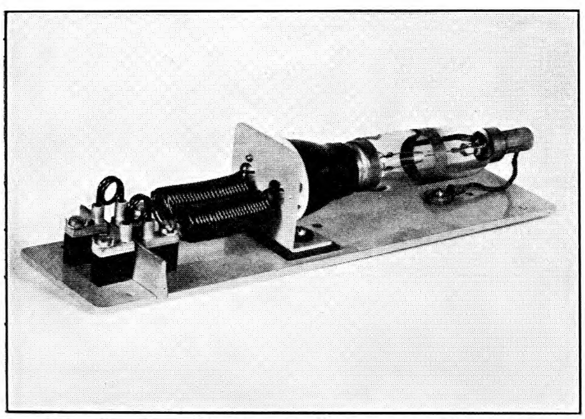


FIG. 5.—GAS DISCHARGE TUBE WITH MOUNTING.

Description and Operation of Tubes.

A typical tube is shown in Fig. **4**, and consists of three symmetrically placed Tungsten electrodes in a pyrex glass envelope which contains a mixture of neon and helium gas at a pressure of about $2\frac{1}{2}$ inches of mercury. The characteristics are chiefly dependent upon the gas pressure, the precise adjustment of which is impracticable under manufacturing conditions, and slight variation between individual tubes is therefore unavoidable. The tubes for the overhead circuits have been made up in panels of 5 ; the panel is of mild steel and is solidly connected to the earthing system. There is little doubt that these tubes will operate in the event of the lines being struck by lightning, and there will be a danger that the heavy currents which they may be called upon to pass under such circumstances would result in physical damage or alteration in the characteristics. To guard against this danger a small coil of 15 turns wound to a diameter

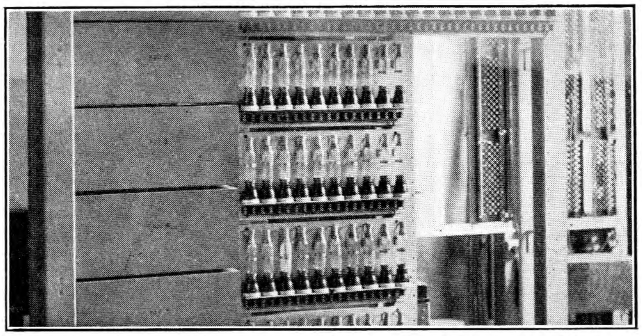


FIG. 6.—TUBES MOUNTED ON STANDARD APPARATUS RACKS.

of $\frac{3}{4}$ in. has been fitted in series with each electrode, and on the line side of this coil a spark gap has been provided ; the spark gap is incorporated in the U link fitting which is similar to that normally used in pole test boxes. The arrangement is clearly shown in Fig. **5** which illustrates a single tube and mounting.

The tubes for the underground circuits are arranged in panels of 10, the panels being drilled for mounting on standard racks (see Fig. **6**.) No protection against lightning is, of course, necessary for these tubes.

The relation between current and voltage across the tube is shown in Fig. **7**; at the point A a glow discharge commences due to ionization of the neon gas. During this glow-discharge period (A-B) the tube behaves similarly to a resistance, the voltage across it increasing with the current. At the point B an arc is struck ; the resistance of this arc decreases very rapidly with increasing current, and consequently the voltage across the tube falls away in the manner shown in the curve. When calculating the current due to induction in a circuit on which tubes are fitted at each end, it is necessary to assess roughly the point of the characteristic on which the tubes will operate, and to determine from the curve the voltage across each ; the remaining voltage in the circuit and the resistance of the circuit will then determine the current.

Considerations Governing Disposition of the Tubes.

It will be seen from considerations discussed later that the voltage above earth on any line can be prevented from reaching a dangerous value by fitting tubes at each end. It must be borne in mind, however, that the tubes are intended to protect men working on the lines, and during such operations it is inevitable that the circuit will sometimes be broken, either intentionally or due to a fault. With a break in any line on a route the tubes connected to that line could not operate and the workmen would be unprotected. For this reason it is desirable to fit tubes at intermediate points, such that the induced voltage between adjacent installations would be of the order of 300 volts. From the point of view of installation and maintenance it is an obvious advantage to fit the tubes in or near towns, and if possible in the exchange buildings. The disposition of towns and villages along each of the routes was found to be satisfactory so far as dividing the lines into 300 volt sections was concerned, and for the Belfast-Banbridge cable accommodation in the exchanges could be easily accomplished. The fitting of the 10 amp tubes in

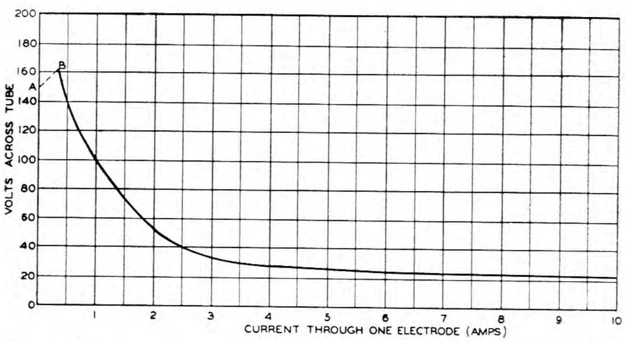


FIG. 7.—RELATION BETWEEN VOLTAGE ACROSS TUBE AND CURRENT FLOWING.

exchanges, however, presented many difficulties and was practicable only in one case, namely Banbridge; in some of the smaller exchanges the accommodation was inadequate; at those exchanges where the circuits requiring protection were terminated, the exchange terminal pole and the M.D.F. were connected by cables of 10 or 20 lb. conductors which were too light to carry the current discharged by the tubes; at the intermediate points it would have been necessary to break the circuits and lead them into the exchange, and this course, with the one exception quoted, would have involved a considerable length of new underground duct and cable. For the foregoing reasons the tubes for the overhead circuits have been installed on poles in a form of a pole test box, as illustrated in Fig. **8**.

The dividing of the line into 300 volt sections was somewhat complicated by the fact that it was necessary to take into consideration the effects of a fault at any point along the power line. By way of illustration consider the curves shown in Fig. **9**; curve I gives the induced volts per ampere of fault current in the Belfast-Newcastle circuits, and curve II the fault current in the power line. The voltage induced in telephone circuits due to a fault at any

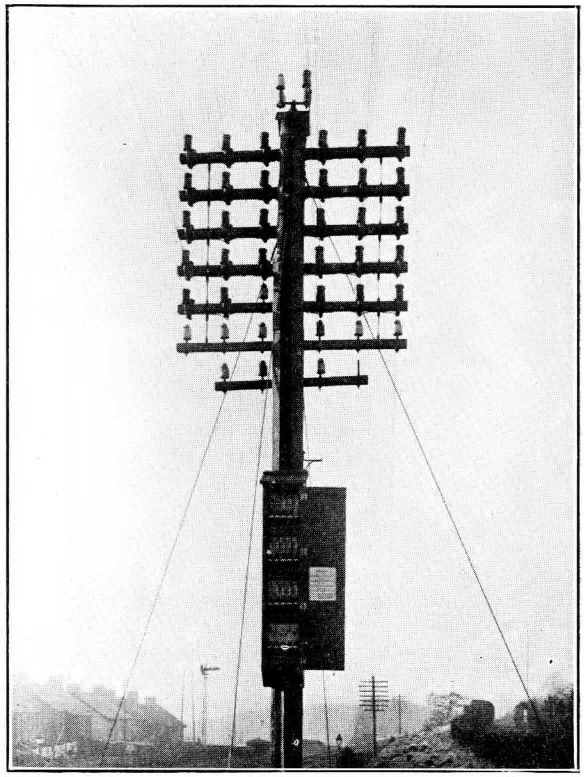


FIG. **8**.—POLE TEST BOX CONTAINING THE TUBES.

point is given by the product of the ordinates of curves I and II for that point; thus a fault at Newcastle will induce a total voltage of $5.25 \times 254 = 1{,}330$ volts in the telephone circuits, and for the same fault, the voltage between the point X and Belfast will be $2.6 \times 254 = 660$ volts. Should a fault occur at point X, however, the induced voltage will be $2.6 \times 480 = 1{,}250$ volts; thus as Belfast is approached the increase in the fault current tends to compensate for the reduction in the length of exposure. The method finally adopted to determine the 300 volt sections was as follows :—

It was first assumed that a fault occurred at Newcastle, where the fault current will be 254 amperes; the induced voltage distribution would then follow

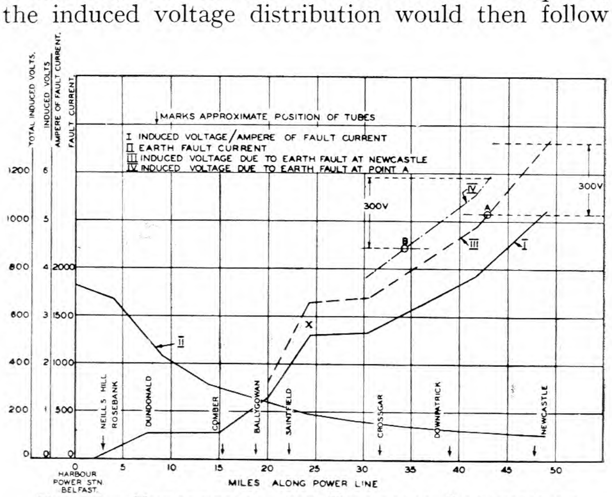


FIG. **9**.—THEORETICAL AND PRACTICAL LOCATION OF THE TUBES curve III of Fig. 9; a distance representing 300 volts was then marked off along this curve, thus obtaining point A. The next step was to assume a fault at point A where the fault current would be 290 amps; the induced voltage then follows curve IV, and by deducting a further 300 volts, point B was obtained. By continuing this process for the whole line the theoretical positions of the tubes can be fixed, but in practice it was necessary to compromise with other considerations such as accessibility for installation and maintenance, low resistivity of soil for earth system, avoidance of transposition poles, etc. The approximate positions of the sites actually chosen for the Belfast-Newcastle route are indicated in the figure.

Earth Systems for Tubes Fitted on Poles.

It was apparent from the outset that where a large number of tubes were to be connected to the same earthing system, this system would need to be of low resistance, otherwise the voltage drop across this resistance due to the current from each tube discharging through it, might prevent the tubes operating satisfactorily.

Assuming n conductors, all of the same gauge, the current discharged from each is given by:

$$I = \frac{E - 2\,ET}{R + n(R1 + R2)} \qquad \ldots\ldots\ldots\ldots (1)$$

where E = voltage induced in each conductor
ET = voltage across the tube for its ultimate operating condition
R = line resistance

R1 and R2 = the resistances of the earth systems at either end of the line.

The value of ET can be derived from the curve in Fig. 7 by making a rough estimate of the current. Alternatively the curve can be assumed to approximate to a rectangular hyperbola, so that I × ET = K, and by substitution in equation 1:

$$I = \frac{E \pm \sqrt{E^2 - 8K\,\{R + n\,(R_1 + R_2)\}}}{2\{R + n\,(R_1 + R_2)\}} \quad \ldots (2)$$

For the 10 amp tubes the value of K may be taken as 100 for values of current up to about 5 amperes.

The effect of the earthing resistance can perhaps best be shown by considering a particular section of line, which allows of simple calculation, e.g. Neills Hill-Comber. At each of these points 15 tubes are installed and the conductors between them are all 150 pounds copper each of resistance 33.3 ohms. If a fault occurred at Comber the induced voltage between the two sets of tubes would be 380 volts.

Substituting in the above equation:

$$I = \frac{380 - 2ET}{33.3 + 30(R1 + R2)}$$

If R1 = R2 = 10 ohms, then I will be of the order of 0·1 amp (see Fig. 7) and for this current ET = approximately 152 volts.

$$\text{Therefore } I = \frac{380 - 304}{33.3 + 600} = 0{\cdot}12 \text{ amp}$$

i.e., the tubes will operate on the glow discharge portion of the characteristic and since there will be slight variation in the characteristics of different tubes it is possible that some may fail to operate.

The above example illustrates the need for a low earthing resistance. The earthing systems actually installed consist of 100 yards of 2 in. lead strip buried at a depth of 2 feet in a 6 ins. × 6 ins. bed of coke.

The theoretical resistance of such a system is given by the formula

$$R = \frac{\rho}{2\pi l} \log \frac{4l}{w} \left\{ 1 + \frac{\log \frac{l}{2t}}{\log \frac{4l}{w}} \right\}$$

Where ρ = earth resistivity in ohms per centimetre cube
l = length of strip in centimetres
w = width of strip
t = depth at which strip is buried, in centimetres.

(The coke bed will effect approximately a 15 per cent. reduction in the resistance obtained by the above formula).

It was assumed for preliminary calculations, that sites could be situated in areas where the earth resistivity would not exceed 10,000 ohms /cm³. and that accordingly the resistance of each earth system would be less than 2 ohms. In actual fact, however, it was extremely difficult to find suitable sites in areas of low earth resistivity. The sub-soil in Northern Ireland is very rocky and those areas which are of low resistivity are liable to be marshy and consequently avoided by the roads and railways along which the Department's routes run. The resistance of each earth system is given in Table 1, and it will be seen that at the terminal points, namely Lisburn, Banbridge, Neills Hill and Newcastle, a satisfactory value has been obtained; at some of the intermediate points, however, such as Downpatrick and Crossgar it was practically impossible to find a suitable site in ground of low resistivity, and consequently the resistance of the earth systems is comparatively high. Since only a few tubes are fitted at these points, the effect of the high earth resistance will not be serious. Considering again the section of line between Neills Hill and Comber, the actual values are:

R1 = 1·6 ohms
R2 = 3·2 ohms

and from equation (2):

I = 1·2 amperes

i.e., there is no doubt that the tubes will operate satisfactorily

It has already been stated that the current-carrying capacity of the tubes is somewhat generous, and from the above example it may appear unduly so. The example was chosen, however, purely on account of the simple calculation it involved. In actual fact, conditions can arise, depending upon the position of the fault, under which the tubes will be called upon to pass a current more closely approaching their full rating. It should perhaps also be mentioned that the high current rating is a useful insurance against damage by lightning.

Table I.

Schedule of Earth Resistances

Site	Resistance (ohms)	Remarks
Lisburn ..	0·8	On River bank
Hillsborough ..	5	Lower sub soil rocky
Dromore ..	3	
Banbridge ..	1	
Newcastle ..	1·5	Bonded to water pipe
Downpatrick ..	8	Very rocky ground
Crossgar ..	8	Very rocky ground
Saintfield ..	1·4	
Ballygowan ..	3·6	Accurate measurement difficult
Comber ..	3·2	
Neills Hill ..	1·6	

Voltage Distribution on a Circuit Fitted with Gas Discharge Tubes.

The simplest case will first be considered of a telephone line fitted with tubes at each end and having a total longitudinal voltage E induced uniformally throughout its length (see Fig. **10**). Assuming that the circuit has no connection to earth then, before the tubes operate, the voltage between line and earth will correspond to curve I of Fig. **11**. If one end of the circuit is connected with earth, and it will be realised that most trunk circuits are normally earthed at one end through a relay, then the other end will rise to the full voltage E, and it is under this condition that the limit to 300 volts is required.

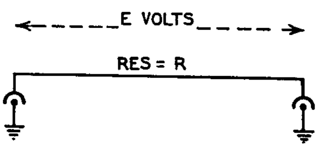


Fig. **10**.—Telephone Line with Tube at each End.

Referring again to Fig. **10**, when the voltage E exceeds 2 ET the tubes will operate and discharge a current I. The induced voltage will then be absorbed by the volt drop in the line and in the earthing system

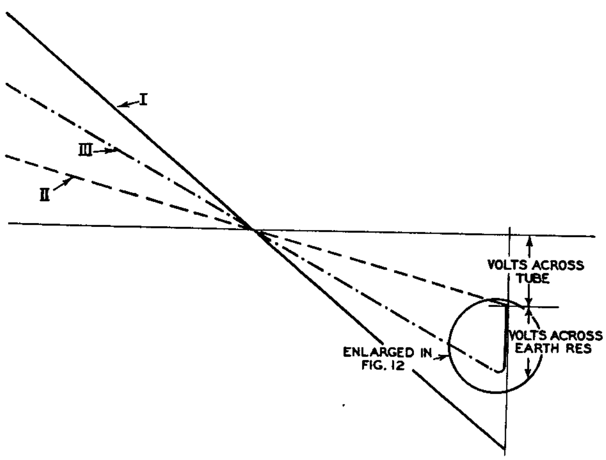


Fig. **11**.—Line Voltage Curves.

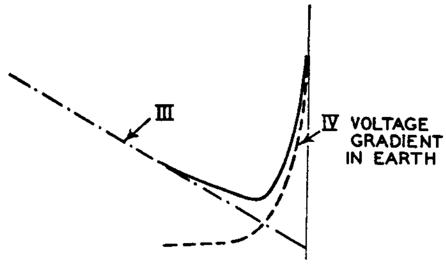


Fig. **12**.—Voltage Gradient in Earth.

and by the voltages across the tubes. Curve II of Fig. **11** represents the volt drop in the line and the difference between curves I and II, *i.e.*, curve III gives the voltage between the wire and earth. The maximum value reached by curve III is practically equal to the sum of the voltages across the tube and across the earthing system. The voltage drop in the earthing system is itself a gradient in the earth radiating from the point where the connection with earth is actually made : the appropriate part of Fig. **11** has been enlarged in Fig. **12**, and illustrates that, at the pole where the tubes are installed, the voltage above earth is equal to the potential difference across the tube, and that the maximum voltage above earth reached by the wire occurs at a point outside the resistance area of the earth system.

As already mentioned a trunk line is normally connected to earth at one end through a comparatively high impedance relay. Before the tubes operate the voltage distribution will be as shown in Fig. **13**. Tube Y will now flash over and as soon as current commences to flow the voltage distribution on the line will be modified to that shown in Fig. **14**. The voltage drop across the relay will be sufficient to operate tube X, and when this occurs the conditions will be practically identical with those shown in Fig. **11**.

The foregoing considerations demonstrate that when the tubes at each end of a circuit are discharging, the voltage above earth at any point along the line will

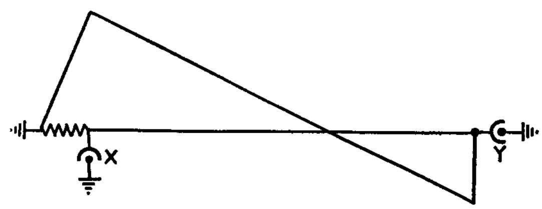


Fig. **13**.—Voltage Distribution before the Tubes Operate.

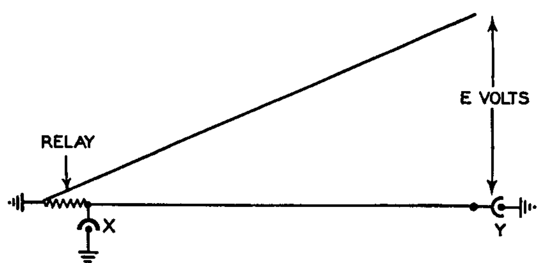


Fig. **14**.—Voltage Distribution after Flash Over.

not reach a dangerous value, and consequently intermediate tubes are not likely to operate.

Method of Connecting Overhead Lines to Tubes.

So far as the operation of tubes is concerned it would be sufficient simply to tee each lead to the line wire, but this method would have a serious disadvantage in that any disconnection in the leads would not be apparent by test. For this reason the line wires were broken at each point where the tubes were fitted, and the leads from the Up and Down sides brought down the pole and the through joint made at the U link fitting on the tubes. The connections are illustrated in Fig. **15** and it will be seen that disconnection of the leads from the tubes must always result in the line being broken ; another advantage of this method of connection is that the U links provide an excellent testing point for line faults.

Installation at Banbridge.

As already mentioned it was practicable to accommodate the tubes for the overhead circuits in the exchange building ; actually they were installed in the amplifier hut and Fig. **16** illustrates the construction adopted. The circuits requiring protection were Belfast-Banbridge 1-4 and 7 ; Belfast-Newry 1, 2 and 7 ; Belfast-Dublin 1-4 6-7. The Belfast-Banbridge circuits were of course already terminated on the terminal pole. The remaining circuits were broken and terminated in the usual manner on terminal blocks (Blocks terminal No. 12), from which cables P.C.Q.S. 8 pair/70 lb. were run to the amplifier hut where they were again terminated on similar blocks. Carrier channels already exist on the Belfast-Dublin 3 and additional channels were in course of provision on one of the other Belfast-Dublin circuits ; in order to avoid cross talk between the carrier channels it was necessary to run the physical circuits in separate cables, *i.e.*, two cables were run from both the Up and Down sides and three of the Belfast-Dublin circuits routed in each.

Cable I.R.V. 1 pair/40 lb. was used for wiring between the blocks in the amplifier hut and the tubes. For the Belfast-Newry and Belfast-Dublin circuits the through connection was made at the point of connection to the tubes in a similar manner to that described in the preceding paragraph, while for the Belfast-Banbridge circuits the U links on the tubes provided the connection between the I.R.V. leads and five of the pairs existing between the amplifier hut and the exchange.

Belfast-Banbridge Cable.

The voltage induced in the Belfast-Banbridge underground circuits is considerably less than that induced in the overhead circuits on account of the screening effect exercised by the cable sheath. Tubes were therefore required only at three points, namely, Belfast, Hillsborough and Banbridge, and accommodation in exchange buildings was possible. The installation in Belfast is shown in Fig. **6,** and it will be seen that the cable has been terminated in standard manner and that the tubes are arranged in panels of ten and mounted on standard racks.

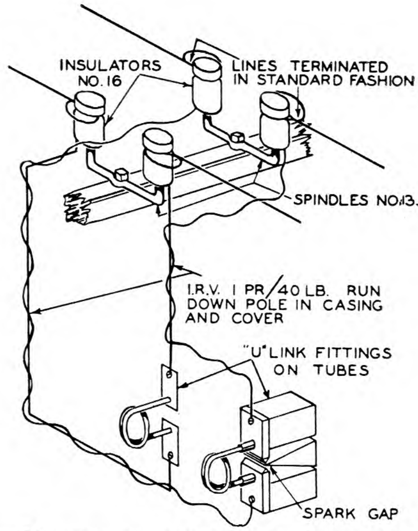


Fig. **15**.—Method of connecting Overhead Lines to Tubes.

Conclusion.

Although, from theoretical considerations, the tubes of the type installed should provide adequate protection for the Department's circuits, the extent to which they can be employed will depend upon their performance in the field, which is being kept under close observation. A metering device is being fitted on selected installations to record the number of times the tubes operate and the information thus obtained will, if possible, be co-related with the faults which occur on the power system.

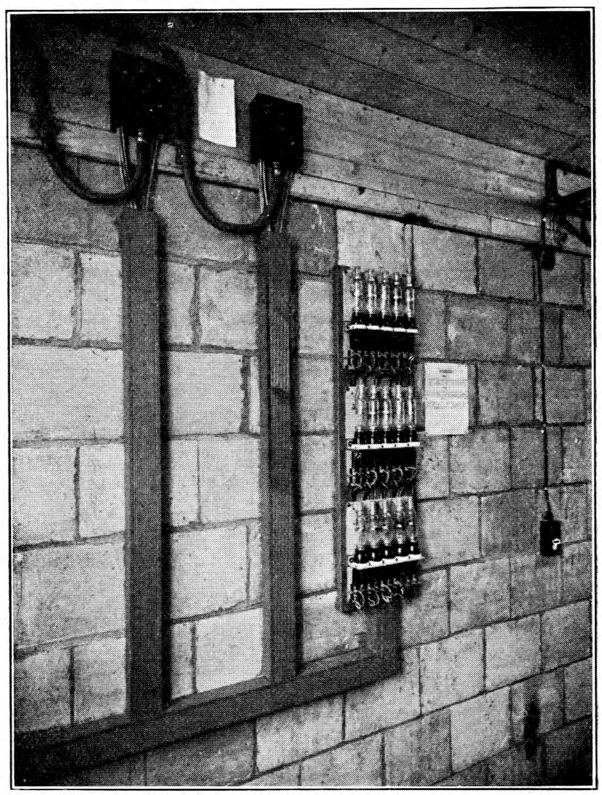


Fig. **16**.—Accommodation of Tubes in Amplifier Hut.

The chief disadvantage of the tubes, so far as overhead lines are concerned, appears to be their susceptibility to damage by lightning; a further disadvantage is that, since accommodation in an exchange building will usually be impracticable, the number of tubes which can safely be fitted on any one pole will be limited by the difficulty of obtaining a low resistance connection with earth. None of these disadvantages, however, can be regarded as serious; there is no reason to believe that the protection against damage by lightning afforded to the tube by the coil and spark gap will not be effective, while the problem of the earthing systems could be overcome by spreading the installation over a number of poles and providing a reasonably good earth at each.

If the field trials prove successful there is no doubt that the tubes will provide a very valuable means of protecting telephone circuits from induced voltages, especially where protective measures on the power system are expensive or impracticable.

APPENDIX I

Calculation of Fault Current in Power Line

The calculation is made by the method of phase sequence components.

Particulars of the maximum plant in use at one time at Harbour Power Station are given in Table 2.

Table 2

	Capacity (kV.A.)	Percentage reactance.	Xp at 33 kV.	Xn at 33 kV.	Xo at 33 kV.
Generator (1)	30,000	20%	j 7·25	j 5	not required
Generator (2)	30,000	20%	j 7·25	j 5	not required
Generator (3)	18,750	10%	j 5·82	j 4·1	not required
Generator (4)	12,500	10%	j 8·75	j 5·9	not required
Transformer Bank (1)	30,000	10%	j 3·63	j 3·63	j 3·63
Transformer Bank (2)	30,000	10%	j 3·63	j 3·63	j 3·63
Transformer Bank (3)	20,000	8%	j 4·4	j 4·4	j 4·4

Resultant $X_{GP} = j1{\cdot}75$

Resultant $X_{GN} = j1{\cdot}23$

Resultant $X_{TP} = X_{TN} = X_{TO} = j1{\cdot}28$

Power Lines.

The Boards' lines radiate from the switching station at Rosebank, which is linked with Harbour Power Station by means of 4.17 miles of high tension line supported on steel towers. The towers carry four circuits, two insulated for 132 kV and two for 33 kV, the conductors being S.C.A. (steel core aluminium) 30/.102 aluminium, 7/·102 steel for the former and S.C.A. 7/·173 aluminium, 7/·076 steel for the latter; a S.C.A., 12/·11 aluminium, 7/·11 steel, earth wire is also provided. The impedance of these four circuits in parallel is (by calculation):

$$Z_p + Z_n + Z_o = 1.45 + j3{\cdot}32.$$

Except for some short lengths of steel core copper, the remaining 33 kV lines radiating from Rosebank comprise:—

Conductors. S.C.A. 6/·161 aluminium, 1/·161 steel; resistance = ·582 ohms/mile; radius = 241 ins.; ψ(internal flux factor) = ·55

Spacing is equilateral at 4 feet.

Based on an earth resistivity of 30,000 ohms cm.,

$$Z_{LO} = {\cdot}82 + j2{\cdot}77 \text{ ohms/mile.}$$

$$Z_{LP} + Z_{LN} + Z_{LO} = 1{\cdot}98 + j3{\cdot}96 \text{ ohms/mile.}$$

Thus by the method of phase sequence components the fault current at any point, "L" miles from Rosebank, will be given by:—

$$I = \frac{\sqrt{3} \times 33{,}000}{{\cdot}82 + j9{\cdot}6 + L\,(1{\cdot}98 + j3{\cdot}96)}$$

With the 10 ohm resistance fitted in the neutral connection with earth

$$I = \frac{\sqrt{3} \times 33{,}000}{30{\cdot}82 + j9{\cdot}6 + L\,(1{\cdot}98 + j3{\cdot}96)}$$

To Find the Value of the Resistance Required to Limit the Induced Voltage to 300 Volts.

Considering the most serious parallelism, namely that with the Newcastle route, the induced voltage is 5.25 volts/amp for a fault at Newcastle. In order that the total voltage induced in the Post Office circuits shall not exceed 300 volts it would be necessary to limit the fault current to $\frac{300}{5{\cdot}25} = 57$ amps.

Newcastle is 45 miles distant from Rosebank and the line impedance (Z_L) is given by

$$Z_L = 90 + j188$$

If R = the resistance required to limit the fault current to 57 amps.

$$= a + jb \qquad \text{where} \sqrt{a^2 + b^2} = 57$$

Then $\dfrac{\sqrt{3} \times 33{,}000}{(3R + 90) + j188}$

from which R = 300 ohms.

Modern Developments in Television

S. T. STEVENS

Part II—Reception Systems

The first part of this article, which appeared in the April issue, dealt with television transmission systems. In this second part the author describes a number of reception systems employing electronic or mechanical scanning.

Introduction.

THE function of any television receiving equipment is to translate the electrical signals received by the aerial into light pictures. The scene at the transmitting end is scanned in a definite order and signals corresponding to the light intensity of each successive part of the picture are sent out. It follows that the function of all receiving systems must be to generate a spot of light of intensity proportional to the received signals and to switch this light spot over the receiving screen in synchronism with the scanning beam at the transmitter.

As in transmitting systems, there are two chief methods of scanning, one electronic and the other mechanical. The former, employing a special form of cathode ray tube, is at present the more promising but certain mechanical scanning systems have been highly developed.

Since this article was prepared the Postmaster General, on the recommendation of the Television Advisory Committee, has authorised the B.B.C. to cease using the Baird system of television at the London television station. As a result all transmissions are now on interlaced scanning at 405 lines per picture and 50 frames per second, each frame consisting of 202½ lines.

Reception Systems Employing Electronic Scanning.

The Cathode Ray Tube.

The principal component of all television reception systems employing electronic scanning is the cathode ray tube and its associated time base units. The elements of the tube are shown in Fig. **1**. A wire or thin ribbon filament is heated by an electric current

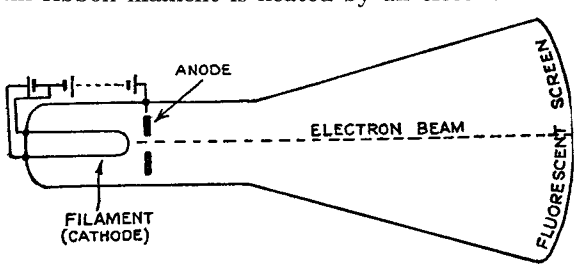


Fig. 1.—Cathode Ray Tube.

and emits a stream of electrons which are drawn to the anode, maintained at a positive potential to the cathode, exactly as in a wireless valve. The anode is usually in the form of a disc with a central hole, or of a short, narrow tube. The electrons are accelerated towards the positive anode by reason of its potential and arrive with such a speed that some shoot right through the anode aperture and emerge into the main bulb beyond, while some are caught by the anode and form an anode circuit current just as in the two electrode valve or diode.

In the journey of the beam of electrons through the main bulb, however, they mutually repel each other, in accordance with the ordinary electrostatic laws of similar charges, so that the beam tends to broaden and diffuse by the time it reaches the fluorescent screen on the end of the bulb.

Calcium tungstate, certain forms of zinc sulphide, zinc-cadmium sulphide, Willemite, etc., are mostly used as fluorescent screens, and a spot of light, dependent in colour on the fluorescent substance used, is produced where the electron beam strikes the screen.

In order to concentrate the stream of electrons so that a more powerful beam is produced, a cylinder surrounds the filament, the cylinder being kept negative to the filament by an amount of 1/10th or 1/20th of the voltage by which the anode is positive. The negative charge on the cylinder exercises an immediate constricting effect on the electrons emitted from the filament due to repulsion and greatly assists their acceleration through the anode aperture. The position of the cylinder is shown in Fig. **2**.

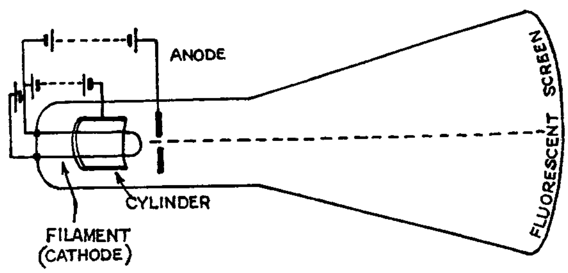


Fig. 2.—Simple Gun Assembly.

An increase in the negative potential applied to the cylinder, or " shield," causes further repulsion of the electrons emitted from the cathode, opposing the pull of the anode and eventually cutting off the flow of electrons forming the beam in exactly the same manner as overbiasing the grid of a thermionic valve cuts off the plate current.

In the simple gun assembly shown in Fig. **2**, however, variation of the negative bias on the shield, while altering the intensity of the spot also affects the focusing of the spot, causing expansion.

The system of electrodes has as its sole function the work of shooting an electron beam along the tube and for this reason is usually termed an " electron gun." The electron beam can be still further focused to a point of light on the screen in much the same way as a ray of light. Instead of lenses of glass electrical lenses are used, made by applying a voltage to a series of cylinders or discs of metal forming further anodes, a zone of abrupt change of field strength from low accelerating to a high accelerating value behaving as a thin convergent lens. The analogy is shown in Fig. 3. As an example of the arrangement, the negative cylinder or shield may have a voltage of 10 negative,

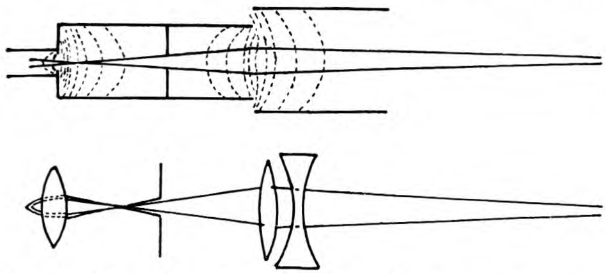


FIG. 3.—FOCUSING THE ELECTRON BEAM AND AN OPTICAL ANALOGY.

the first accelerating anode 500 positive and the second accelerating anode 2,000 positive, and if this ratio of voltage between anodes one and two is altered the focus will be blurred. This is analogous to altering the distance between lenses when a ray of light is sharply focused. The dotted lines in the figure represent the electric field between the two accelerators, and the electrons are guided by the contour of the lines. In the optical analogy if the lenses are moved the beam will not focus at all. In certain hard vacuum tubes now used for television reception, focusing is brought about by the electron lens action of the field between the second and third anodes, a cylinder and disc respectively, as shown in Fig. 4 which also shows a suitable circuit for supplying

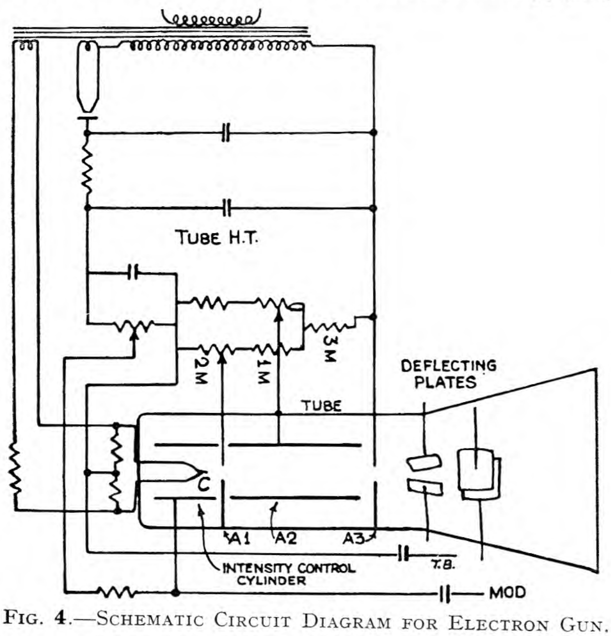


FIG. 4.—SCHEMATIC CIRCUIT DIAGRAM FOR ELECTRON GUN.

the necessary potentials. A typical gun assembly employing three anodes is shown in Fig. 5.

To reproduce the picture modulation it is necessary to vary the strength of the light spot caused by the beam. The intensity of the light spot is proportional to the number of electrons reaching the screen, therefore the number of electrons must be varied without varying the size of the spot, since this must be kept constant to fit in with the scanning. The electron lens action of the gun assembly, shown diagrammatically in Fig. 4, effectively checks any distortion of the spot size due to modulation. Modulation of the electron beam is carried out by placing a fixed negative potential on the shield and modulating from the

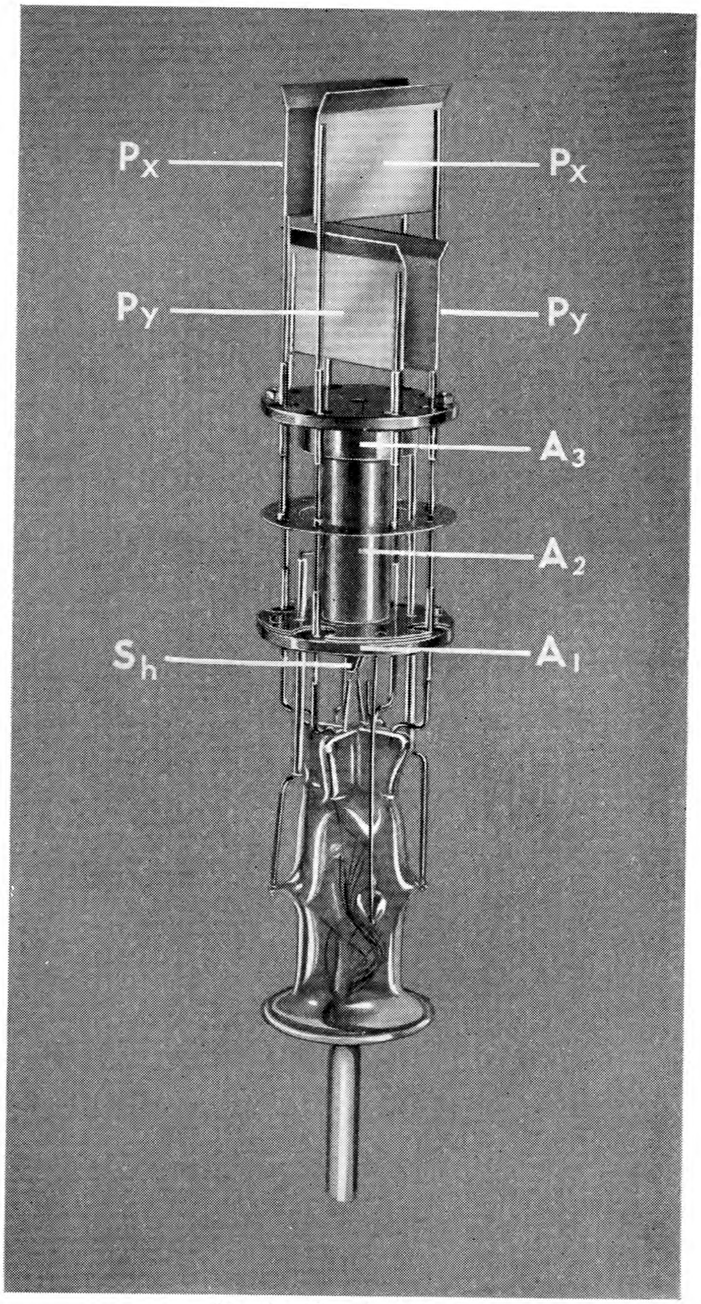


FIG. 5.—GUN ASSEMBLY.

output of a radio receiving set via a resistance capacity circuit.

Deflection of the beam has now to be accomplished to give the scanning sequence as determined by the transmitter. After passing the last gun electrode the electron beam passes between two sets of deflecting plates, one pair providing a vertical deflection and the other a horizontal deflection of the beam. The deflecting plates act like a pair of prisms in a light beam. The deflection in each direction is produced by the action of a potential, of the required wave form, applied to the appropriate pair of deflecting plates. Since the beam consists of a stream of negative electrons it will be attracted to a conductor which has a positive potential upon it and repelled by a negatively charged plate.

Alternatively, the beam may be deflected magnetically by means of coils placed about the neck of the tube. The electron beam may be considered as a current flowing without a conductor, in the ordinary sense of the word, and therefore being capable of deflection by a magnetic field.

The potentials to be applied to the two pairs of deflecting plates must be of sawtooth form in order to bring about a horizontal traverse across the screen at a constant velocity, followed by an extremely rapid return. At the same time, a complete vertical traverse must take place every 240 horizontal traverses, followed by a rapid return to the point of origin of the picture area.

Interlaced scanning is brought about by making the horizontal deflecting frequency an odd number (405) and doubling the vertical frequency (50). By this means all odd numbered lines are scanned first, then all the even ones, or vice versa, in effect scanning 50 pictures per second each of 202½ lines.

The two scanning motions must be synchronised to be in step with the corresponding motions at the transmitter by means of saw-tooth wave generators, or time bases, under the direct control of the transmitter.

The Time Base Unit.

The simplest form of time base unit consists of a condenser charged from a direct current source, through a resistance, which may be varied to alter the rate of charge of the condenser, together with a device which discharges the condenser periodically. A neon glow lamp has characteristics which enable it to function more or less satisfactorily as the discharging device.

A neon lamp will not pass current until the potential across the terminals reaches a specified voltage, known as the striking voltage, when the current rapidly rises to a saturation value. If the lamp is connected across a condenser which is fed through a high resis-

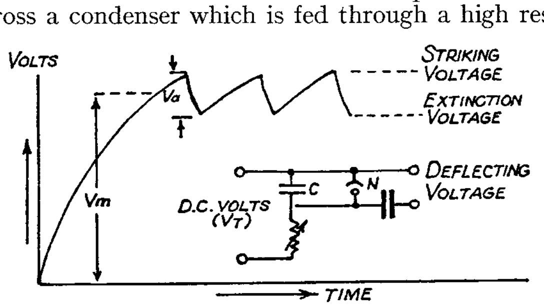


FIG. 6.—VOLTAGE CURVE OF NEON LAMP TIME BASE UNIT.

tance, the potential across the condenser plates falls until the extinction voltage of the lamp is reached, when the condenser proceeds to recharge. Such a time base gives a deflection which is exponential with reference to time, as shown in Fig. **6**. The circuit is wasteful in voltage as only the difference between the striking and extinguishing potentials of the neon lamp is utilised. The exponential charging curve may be made more linear by using a saturated diode in place of the variable charging resistance, the rate of condenser charging being controlled by a variable resistance altering the anode current flow of the diode. Such a circuit is shown in Fig. **7**. The circuit is synchronised by the introduction of a pulse into the

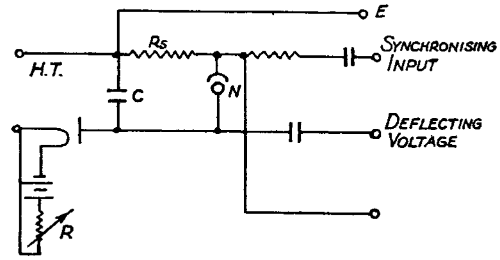


FIG. 7.—TIME BASE CIRCUIT USING NEON LAMP AND SATURATED DIODE.

resistance "Rs" where it is, in effect, added to the potential across the condenser. Such a pulse, applied between the synchronising terminal and the point "E," which should be connected to earth and the third anode of the cathode ray tube, can determine the exact time at which the discharge occurs, if the time base is adjusted to operate at a slightly lower rate than that to which it is to be synchronised.

The thyratron, or grid glow tube, is a better means of discharging the condenser circuit. This is a mercury vapour, neon, or helium filled triode valve, usually indirectly heated, having the property that if the grid is held sufficiently negative no discharge occurs even with a high anode potential. If the negative charge on the grid is reduced to a low value, the gas is ionised and a heavy discharge occurs, continuing until the anode volts fall to the extinction value of about 15 volts. Deflecting voltages of the order of 500 volts can thus be obtained. In practice the grid is biased to a few volts above that necessary for striking, the action of the synchronising input destroying this balance and allowing the tube to strike.

A circuit employing a thyratron and diode is shown in Fig. **8** and a similar circuit employing a pentode

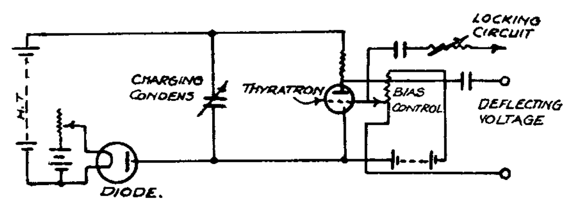


FIG. 8.—TIME BASE CIRCUIT EMPLOYING A THYRATRON AND A DIODE.

charger is shown in Fig. **9**. A pentode used in place of the diode allows the anode current to be altered by control of screen volts on the pentode and a closer approximation to truly linear time deflection is also produced. As previously stated, the time base is connected to earth and the third anode of the cathode ray tube, and as the deflecting voltages are of the order of 500 volts or more some slight distortion due to defocusing of the electron beam may occur owing to this high deflecting voltage. Better time bases arrange that the mean potential on the deflecting

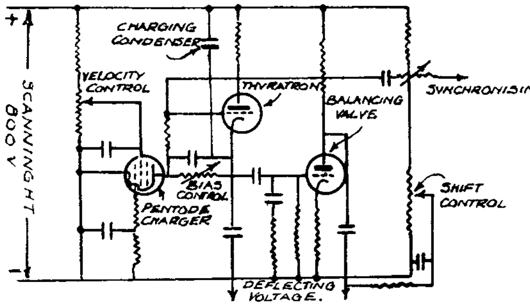


FIG. 9 —TIME BASE CIRCUIT EMPLOYING A THYRATRON AND A PENTODE CHARGER.

plates is kept at the same value as that of the third anode of the cathode ray tube, and to effect this a balancing stage has been added in Fig. **9**.

It is, of course, understood that each pair of deflecting plates in the cathode ray tube will require a time base. The time base shown in Fig. **9** is suitable for the generation of the frame scan frequency.

Mercury vapour has a somewhat long de-ionisation time and tubes of this type cannot be used satisfactorily above two or three thousand c.p.s., whereas the interlaced scanning system of E.M.I. needs 10,125 c.p.s. from the line scanning time base.

Neon and helium filled tubes are rather better since their de-ionisation time is shorter and they will successfully operate at frequencies of 10,000 c.p.s. and upwards. Grid glow tubes, however, are not absolutely constant at high frequencies, being affected by temperature variations, and time bases employing hard valves are now mostly used as line scan generators, leaving the slow 25 c.p.s. frame scan to a thyratron.

The circuit of such a time base is shown in Fig. **10**. The linear sweep is obtained by the charging

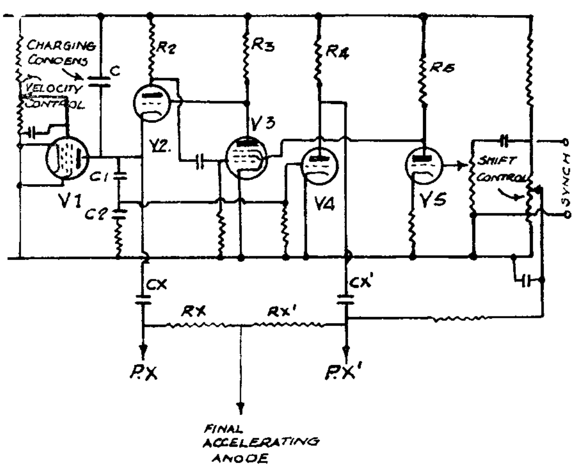


FIG. **10**.—TIME BASE CIRCUIT FOR LINE SCANNING.

of the condenser " C " through a constant current device. This consists of a screened pentode valve, V1, operated on the flat part of its anode voltage—anode current characteristic. " Velocity " control of the sweep is obtained by varying the screen voltage. The flyback discharge is obtained by means of the pair of hard valves V2 and V3 as follows :—During the charging of the condenser the valve V2 takes no anode current owing to its being biased beyond cut-off by the drop in the resistance R3 in the plate circuit of V3. As the charge continues, the voltage across V2 rises until a point is reached where anode current commences to flow ; this causes a voltage drop over the resistance R2 which is fed through a condenser on to the grid of the valve V3 ; this reduces the current in R3, causing the grid voltage of V2 to rise and the anode current to increase, the action being cumulative. At the end of the discharge, the current in R2 drops, reversing the cumulative action and the circuit resets itself for the next charging stroke.

Valve V4 is added to give balanced deflection, being a triode with a characteristic which can be effectively straightened over the necessary range by means of the high resistance R4 in its anode circuit. The condenser potentiometer C1, C2, should divide the voltage on V1 anode by the gain ratio of the valve V4. The anodes of V1 and V4 thus perform saw-tooth voltage excursions of equal amplitude and opposite phase. These voltages are fed to the deflector plates PX and PX^1 via the condensers CX and CX^1, the plates themselves being tied to the final accelerating anode with high resistances RX and RX^1.

Synchronism is carried out in the following manner :—

The screen of V3 is fed by the potentiometer, consisting of the valve V5 and its anode resistance R5. When the synchronising signal is applied to the grid of V5, the positive peaks of the signal will increase the anode current of V5 causing a greater voltage drop across R5 and a consequent reduction in the screen volts on V3, thus raising the grid volts on V2 and initiating the discharge of the condenser C.

RECEPTION SYSTEMS EMPLOYING MECHANICAL SCANNING.

Mihaly-Traub Stationary Mirror Drum System.

Mechanical scanning systems seem to be, at the moment, ousted by the cathode ray tube receiver, and as far as is known no high definition mechanical receiver is yet on the market. There are, however, one or two systems of mechanical reception that may, with development, give satisfactory results and be as cheap or cheaper in operation than the electrical scanning method. One of these is the Mihaly-Traub stationary mirror drum system and Fig. **11** shows the elements of the system.

A small synchronous or electrically controlled motor rotates a polygon of eight vertical mirrors, each mirror set at a slight angle from the vertical and its neighbour, so that there are four mirrors either side of the true vertical. At a certain distance from the rotating mirror drum and parallel with its centre there is placed a quarter of an arc of vertical stationary mirrors, their mirror surfaces facing the rotating mirror drum. For a 240 line scanning system there would be needed **30** stationary mirrors. Each stationary mirror is set at a slight angle from the vertical, and its neighbour, so that there are 15 mirrors either side of the true vertical.

The modulated light source is focused on the lower

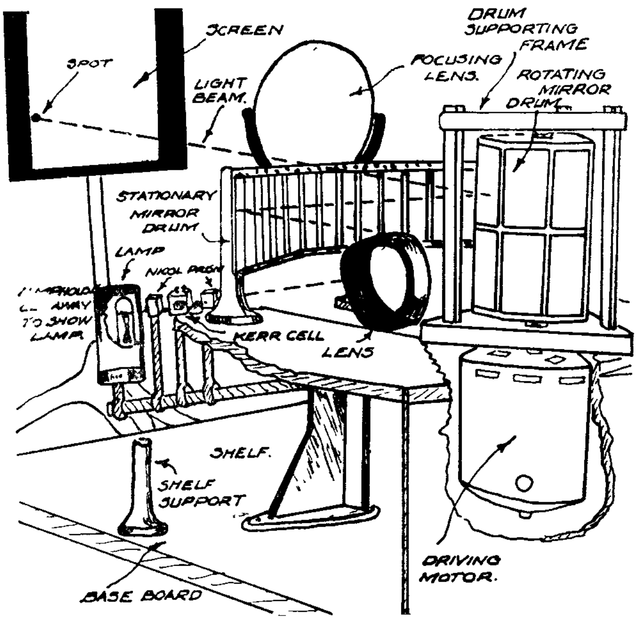


FIG. 11.—MIHALY-TRAUB MIRROR DRUM SYSTEM.

half of the rotating mirror drum from an angle of about 10 degrees below horizontal. If the rotating mirror drum be considered such that the light strikes the first of the series of eight mirrors and is reflected on to the right-hand edge of the right-hand, or outside, fixed mirror, the angle of reflection will be approximately 10 degrees above horizontal. The light will again be reflected at an angle of 10 degrees above horizontal, or at a total angle of 20 degrees, again striking the mirror drum but in the upper half of the same mirror. A total reflection angle of 20 degrees is again made, the light then being focused by means of a lens into the top right-hand corner of a ground glass screen, when viewed from the apparatus side.

When viewed from the outside, the spot of light will appear in the top left hand corner of the ground glass screen. As the rotating mirror reflects the beam of light across the first fixed mirror, the spot of light, as viewed from the outside of the ground glass screen, will move from left to right, describing a line of light. The beam of light is now reflected from the second fixed mirror, which, being at a slight angle to its predecessor, causes a line of light to cross the screen from left to right immediately below that previously drawn by the first mirror reflection.

The beam of light is reflected in like manner from each of the remaining fixed mirrors, the net result being a band of 30 lines of light drawn across the top one-eighth of the screen depth.

The rotation of the first rotating mirror is now such that no reflection from its surface is possible and the second of the series of eight has moved into the path of the modulated light. The reflection from this mirror with each of the 30 fixed mirrors is again carried out, 30 lines of light being drawn on the screen. The second rotating mirror is at an angle slightly nearer the vertical than its predecessor so that its angle of reflection will be correspondingly less than that of the first. Its band of 30 lines will fall immediately below the band of 30 lines drawn by the first mirror and will occupy the second one-eighth of the screen's depth.

This cycle of operations is carried out by each of the eight rotating mirrors in turn, in one revolution of the drum the net result being a series of eight bands of thirty lines, i.e., 240 lines, filling the screen. Viewing the screen, then, from the front, an observer would see a series of 240 lines drawn, one below the other, so that the entire screen was filled.

The rotating mirror drum rotates at 25 revs. per second, or 1,500 revs. per minute, giving the required picture frequency of 25 per second. The density of the light spot would be varying in sympathy with the transmitted signal during the whole scanning process, the result being that each picture element would take its appropriate place in the scanning field and so build up the picture.

The modulation of the light beam may be accomplished by means of a Kerr cell assembly, directly by the use of a gas discharge lamp of the crater pattern, or a combination of these two methods. The size and square shape of the reflected light beam is obtained by the use of a mask with a suitable perforation and a lens assembly, placed in the path of the primary beam.

In order to cope with two scanning standards, one of which requires line interlacing, the Traub Mirror Drum system has been modified as shown in Fig. 12, and operates as follows :—

Light from the lamp "L" passes through a polarising prism " P," a Kerr cell " K," a second prism " P_1," and an aperture " A " on to one of the mirrors of a high speed or line-scanning drum " L." This drum carries nine facets and, in addition, is associated with five stationary reflectors " S " which have the effect of multiplying the effective number of scanning lines thrown on to the slow moving or framing drum " F." Thus each rotation of the drum " L " produces $9 \times 5 = 45$ scanning lines, so that a speed of 8,000 revolutions per minute is sufficient to produce 6,000 scanning lines per second (240×25) which is necessary for the reception of the Baird standard.

A speed of 13,500 revolutions per minute would be necessary for the reception of the Marconi-E.M.I. standard. An increase in the number of stationary reflectors " S " would give a corresponding reduction in the speed of the line-scanning drum, 10 stationary mirrors, for example, producing $9 \times 10 = 90$ scanning lines thus halving the speed of the line scanning drum for each of the two examples given above.

If the slow moving or framing drum " F " were fitted with 25 mirrors angularly spaced around its periphery and rotated at a speed of one revolution per second, then, during the time taken to produce 240 scanning lines by the line-scanning drum (1/25th seconds), one face of the framing drum would move the line scanning from top to bottom of the screen. If the two motions were in synchronism with the transmitter then the 240 lines would be correctly spaced on the screen to form one complete picture to the Baird standard.

Taking the Marconi-E.M.I. standard the framing drum would have to rotate at a speed of two revolutions per second since 50 pictures per second are transmitted by this system. In 1/50th seconds the line scanning drum will have produced $202\frac{1}{2}$ scanning lines and if the system is in synchronism with the transmitter the receiver screen will have been scanned by $202\frac{1}{2}$ alternate lines. The following mirror of the framing drum also scans the receiver screen by means of $202\frac{1}{2}$ alternate lines, these so interlacing with the previous scan as to fully scan the screen by means of 405 lines in 1/25th seconds.

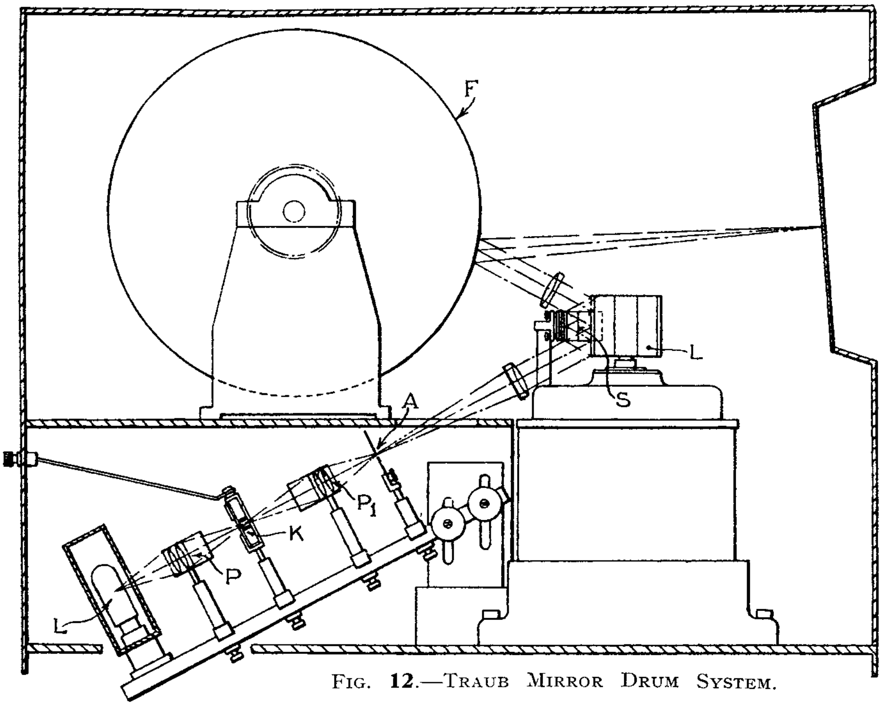


FIG. 12.—TRAUB MIRROR DRUM SYSTEM.

The Mirror Screw.

The mirror screw was evolved from combining the advantages of the nipkow disc, namely, simple and exact scanning of a permanent character, with the picture size obtainable with the mirror drum. A helically formed scanner such as the mirror screw consists of a series of laminations arranged in such a way that the number of mirrors formed by their polished ends determines the number of lines capable of being received, the thickness of the lamination determines the width of one line and the length of the lamination determines the length of one line.

A number of laminations, dependent on the number of lines to be received, is then piled on top of one another and twisted to form a spiral of one convolution, something like a spiral staircase. If such an assembly is rotated at speed, it will appear, to all intents and purposes, as a solid mirror. If a signal modulated light of a suitable shape is reflected on the mirror faces during the scanning movement, a television picture can be built up. The light source shape must be a long thin line. This is because in one dimension the mirror screw acts as a mirror drum and in the other as an aperture in a disc. One dimension is given automatically, due to the laminations being on top of one another in the screw pile, the other dimension being given in the width of the light line which will be the same as the thickness of one lamination, or, in other words, the reflection of the light line width, in the thickness of one lamination, should be equal to one picture element. A mirror screw built to the high definition scanning standards could be assembled in the following manner. Let a picture shape of $7\frac{1}{2}$ inches by 10 inches be required, i.e. of the 3×4 ratio. The number of laminations required would be 240, 10 inches long and $\frac{1}{32}$nd inches thick, since

$$\frac{7.5 \text{ inches}}{240 \text{ lines}} = \frac{1}{32}\text{nd inches.}$$

The laminations are usually mounted in a pile with parallel faces and then optically polished and silvered in one piece. The laminations are then separated, only the ends required as mirrors being of a reflecting nature. Flat stainless steel or brass strips are used.

These laminations are then piled on top of one another and spirally placed so that the progressive angle between one and the next is $\frac{360°}{240}$ or $1\frac{1}{2}$ degrees. A mirror screw so adjusted would appear as a solid mirror $7\frac{1}{2} \times 10$ inches when rotating. A light source $7\frac{1}{2}$ inches long and $\frac{1}{32}$nd inches thick would be needed, placed parallel to the axis of the screw so that a spot of light $\frac{1}{32}$nd inches square would be visible to the eye at any one particular moment. One method of locking the laminations is to have a series of slots in each lamination which interlock by means of a screw to the previous one. The axis of the mirror screw is vertical, and the direction of rotation anticlockwise. When the scanning action is analysed it is seen that, beginning with the topmost lamination of the pile, the line of light, apparently $\frac{1}{32}$nd inches square moves from left to right across the field of view and passes away. The second lamination now appears and draws a line of light below that drawn by the first, finally passing from view. This process is repeated for each of the 240 laminations. If the line of light is being modulated during the scanning action the various elements are built up into their appropriate positions in the received television picture. The mirror screw would need to rotate at 25 revs. per second to give the required picture frequency.

As the received picture is viewed directly in the mirror screw the best place for viewing the image would be as near the light source as possible, and, using plane laminations, this distance is 4-5 metres. By the use of curved laminations this distance may be reduced to 1.5-2 metres as shown in Fig. **13**. A mirror screw is shown in Fig. **14**.

The line of light may be obtained by the use of a Kerr cell (Fig. **15**) of suitable shape in conjunction with a pair of cylindrical condenser lenses which extend the length of the light source in one dimension.

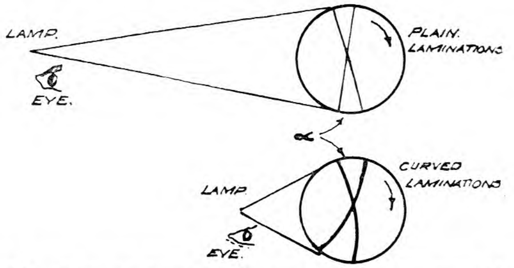


FIG. **13**.—USE OF CURVED LAMINATIONS FOR THE MIRROR SCREW.

The complete arrangement is shown diagrammatically in Fig. **16**.

The Scophony Optical-Mechanical System.

Full details of this system, which promises to be the most successful of mechanical receivers, have not yet been published but the following is a general description. It is understood that receivers are to be built in three sizes, the " Home Receiver " giving a

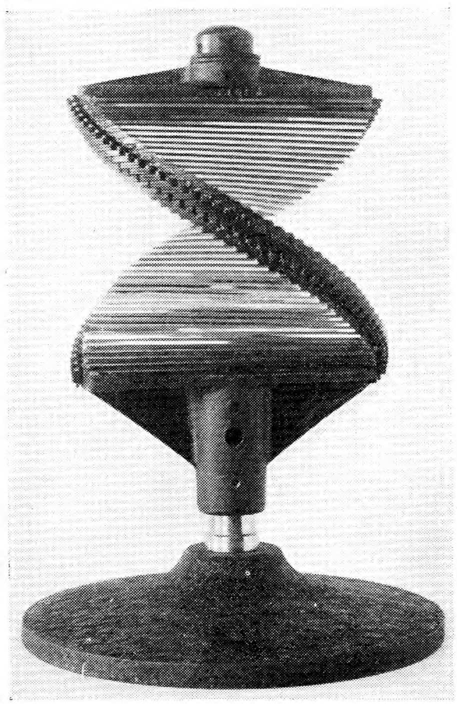


FIG. **14**.—MIRROR SCREW.

16-inch picture, the " Medium Screen Receiver " a 4 ft. 6 inch picture and the " Large Screen Receiver " a 13 ft. by 10 ft. or larger, picture. The Home Receiver utilises a metal filament lamp of the sound film exciter lamp pattern while the other receivers use an arc lamp.

The modulation of the light from the arc source is effected by varying the retardation of the light waves by zones of differing pressure in a liquid such as water or kerosene, the latter giving the best results.

Locally generated waves at a supersonic frequency of 10 mega-cycles per second are propagated in the kerosene by means of a piezo - electric crystal forming one side wall of a small glass-sided trough as shown in Fig. **17**, the waves passing from left to right while the light beam passes through it in a plane at right angles to the waves. The amplitude of these waves is controlled by the modulating incoming signal and the greater their amplitude, the greater the retardation caused in the light wave. This results in the production of interference waves which may be cut off by means of a narrow slit.

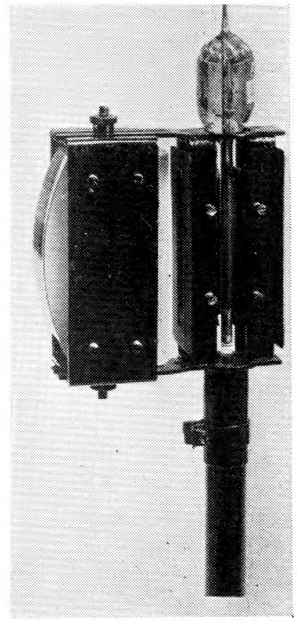


FIG. **15**.—KERR CELL.

The train of waves so formed moves at a calculable speed across the cell, and if a scanning system is used which travels at the same speed as the groups of propagated waves, but in the reverse direction, the effect is one of a considerable number of scanning

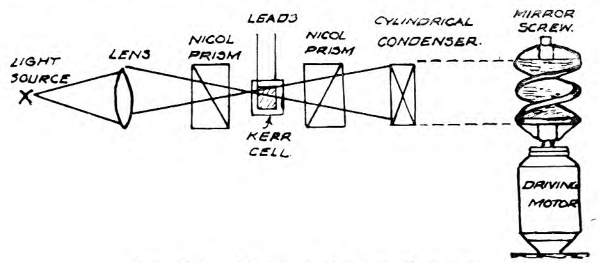


FIG. **16**.—MIRROR SCREW SYSTEM.

points reproduced simultaneously on the screen. The number of points reproduced depends on the length of the cell, approximately 70 points being at present used, the virtual result being that the efficiency of the scanning system is increased 70 times. The efficiency of the Scophony light control

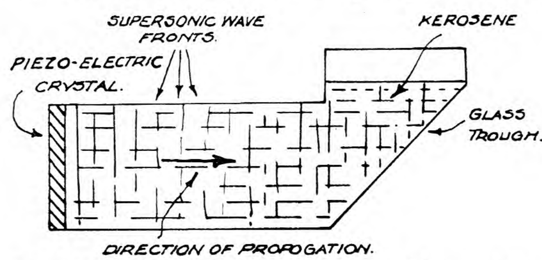


FIG. **17**.—SCOPHONY METHOD OF LIGHT MODULATION.

is shown by the fact that a power of one watt of modulated current only is needed to control the light from a 40 ampere arc.

The high speed scanner used in the Home Receiver is a small mirror drum, 4 cms. long by 1 cm. in diameter, having 20 faces each 1.6 mm. wide, rotated at a speed of 1,800 r.p.m. by a small electric motor consuming only 5 watts, this being kept in step by the synchronising signals. The scanner works in conjunction with a small beam convertor which changes the fan-wise motion of the flat light beam from the tiny mirror drum into an edgewise sliding motion to give the line scanning. This device is in appearance like two ratchet-faced mirrors placed at right angles as in Fig. **18**. the full number of faces not being shown.

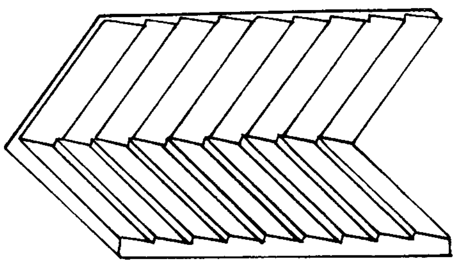


Fig. **18**.—Beam Converter.

The disposition of the various components, which work on the same principle for all the receivers, is shown in Fig. **19**. The light from the arc " A " is focused by the lens assembly " B" and reflected at

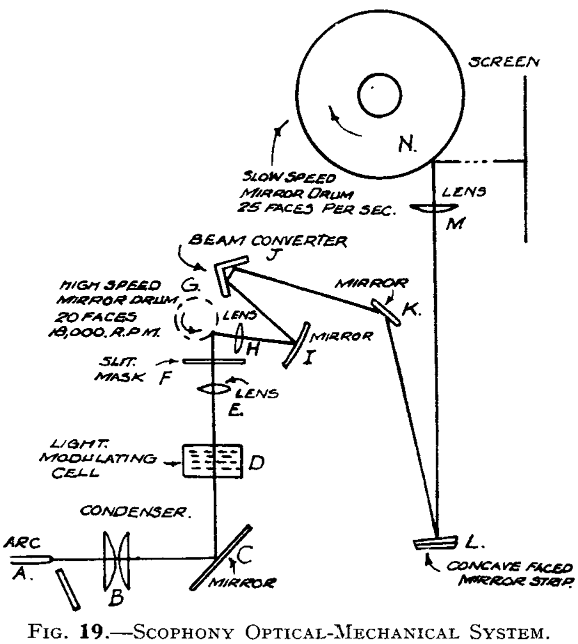


Fig. **19**.—Scophony Optical-Mechanical System.

the mirror " C " through the light modulating cell " D." A cylindrical lens " E " focuses the modulated light upon the slit mask " F " to the mirror drum " G." The lens " H " and concave strip mirror " I " reflect the beam on to the beam convertor " J " and thence via the mirror " K " to the concave strip " L " over which the beam moves in a line scanning trace. This line trace is focused by the lens " M " on to a low speed mirror drum " N." This mirror drum " N " moves the line scan vertically down the screen to give the necessary frame repetition frequency. The slow speed mirror drum is rotated by a phonic wheel type motor to achieve synchronism.

Receiver Circuits.

The design of circuits for the reception of high definition television offers a wide field for research. Two widely differing circuits are shown in Figs. **20** and **21**. Fig. **20** is the circuit of a six-valve

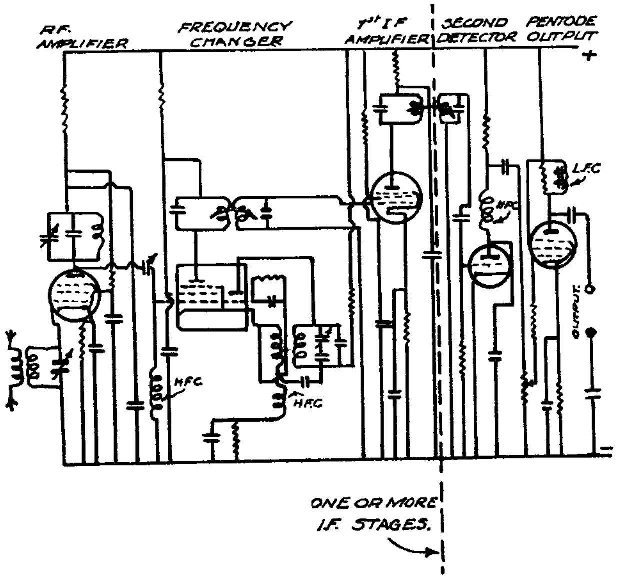


Fig. **20**.—Typical Television Receiver Circuit.

superheterodyne receiver having a 2½ megacycle per second response. The receiver consists of one signal frequency amplifier, frequency changer, two stages of I.F. (only one shown), second detector and pentode output. If necessary a third I.F. stage may

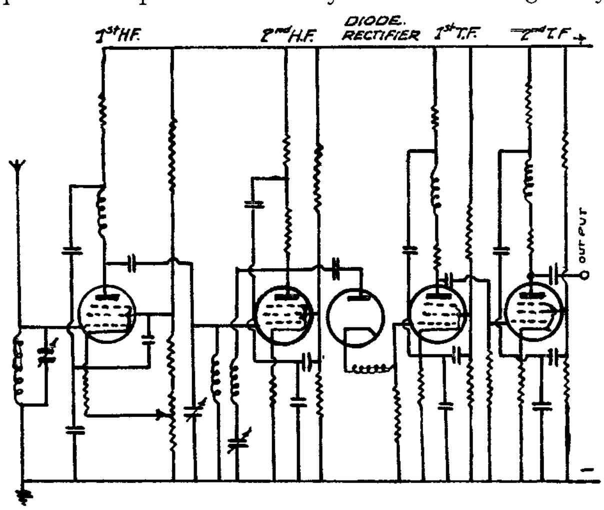


Fig. **21**.—Alternative Television Receiver Circuit.

be added. H.F. pentode valves are used in the H.F. and I.F. stages, a pentode-triode as a frequency changer, triode detector and L.F. pentode output.

The I.F. transformers are tuned to a frequency of

12 megacycles per second, the coupling between the primary and secondary windings being variable in order to obtain any degree of band width up to $2\frac{1}{2}$ megacycles per second. The insulation used throughout is megacite, a special low loss, high power factor material, while the radio frequency coils are self supporting, consisting of a few turns of stiff copper wire. The frequency changing is done by cathode injection; i.e., feeding the incoming signal through the coupling coil of the oscillator circuit.

Fig. **21** illustrates a circuit employing two stages of H.F. amplification. These comprise a variable-mu screened pentode fitted with a cathode circuit volume control, this stage being followed with a second screened pentode. The anode circuit of the second valve is not tuned but has a resistance load instead. Reaction is relied on to compensate for the loss of amplification due to the absence of tuning. Diode rectification is used, coupled to the first L.F. valve by a filter circuit passing all television frequencies up to 1 megacycle. Although the last two stages have been called L.F., compared with the normal sound receiving set these are H.F. stages. Special coupling arrangements are used between the two screened pentodes used for amplification of the television frequencies. Great care has to be taken in screening the various stages from one another as in all ultra short wave receivers.

Aerial design can also influence reception to a very large degree. A half wavelength dipole aerial, centre fed, with multiple quarter wavelength feeders has been found to give good results.

In conclusion the author wishes to thank the Editor of the Television and Short Wave World and Messrs. A. C. Cossor for the loan of blocks.

Bibliography.

"The Fernseh—A.G. Television Systems." by Dr. Alfred Gradenwitz. Television To-day, Vol. I.

"The Baird Electron Camera," by V. A. James. Television and Short Wave World, September, 1936.

"The Electron Multiplier and its Application to Television," by Norman W. Maybank. Television To-day, Vol. I.

"The Possibilities of the Iconoscope in Television," by Dr. V. K. Zworykin and Dr. G. A. Morton. Television To-day, Vol. I.

"The Cossor Cathode Ray Oscillograph," by A. C. Cossor, Ltd.

"The Time Base," by O. S. Puckle. Television To-day, Vol. 2.

"The Scophony Light Control," by J. H. Jeffree. Television and Short Wave World, May, 1936.

"Large Screen Television Development," by R. H. Cricks, F.R.P.S. Kinematograph Weekly, August 20th, 1936.

Wooden Pole Arms

For a number of years the Post Office has been able to obtain supplies of timber from Australia for making into pole arms. There are signs, however, that there may be difficulty in the future in obtaining the requisite quantities of suitable timber from this source. A recent estimate of the acreage of timber available in millions of acres, gives the following figures :—

Jarrah, Eucalyptus marginata	8
Karri, Eucalyptus diversicolor	1.2
Wandoo, Eucalyptus redunca	7
Various Gums, Eucalyptus, microcorys pilularis, etc.	4

The remaining supplies are being consumed at increasing speed, owing to the fact that more of the timber is being used in the Australian home market.

On this account, it was considered desirable to open up other sources of supply, having always in mind a preference for British Colonial products. Following consultation with the market development officer of the Colonial Forest Resources Development Department, and with the co-operation of several timber importers, specimens of certain colonial timbers have been tested with a view to their approval for use as wood arms and possibly for other purposes.

The result, so far, has been to add to the list of approved timbers the following woods :—

Wandoo, Eucalyptus (Australia),
Greenheart, Ocotea Rodiaei Mez (British Guiana),
Danta, Cistanthera papverifera (Gold Coast),
Kruin, Dipterocarpus (British Borneo),
White Serayeh, Shorea plagata (British Borneo).

Formulæ for the Calculation of the Theoretical Characteristics and Design of Coaxial Cables

R. F. J. JARVIS, Ph.D. (Eng.) and G. H. FOGG, B.Sc. (Eng.).

This article, the first of a series, summarises formulæ and gives curves for the rapid design of coaxial cables, with particular reference to their use for television purposes. It will be followed by articles giving details of the coaxial cables and repeater equipment now being installed in Great Britain.

1. SUMMARY.

FORMULÆ are first given for the resistance and inductance per unit length of coaxial cables applicable at all frequencies and to any thickness of wall in the core or sheath, and these are followed by asymptotic formulæ applicable at high frequencies. These formulæ have been expressed in terms of hyperbolic functions which have been plotted graphically so that rapid determinations of resistance and inductance can be made.

After giving the formula for the capacity per unit length, it is shown how the attenuation, phase delay[1] and differential delay can be calculated from the values of the primary constants of the cable, and formulæ for these quantities are developed from the formulæ for the primary constants.

Consideration is then given to four special types of coaxial cable having copper conductors and different combinations of wall thicknesses in the core and sheath, and formulæ are derived in respect of these four types of cable for the attenuation, phase delay and difference in phase delay at two different frequencies. Curves have been drawn from which the attenuation and phase characteristics of these types of cable are quickly deduced.

Finally an outline is given of the method of applying the relevant formulæ to the design of coaxial cables from the point of view of either the attenuation characteristics alone, or of both attenuation and phase delay characteristics.

It is shown how thin walled conductors may possess very considerable advantages in coaxial cables intended for television transmission, owing to the reduced difference in phase delay between the maximum and minimum frequencies of the transmission band. Detailed conclusions regarding this are summarised in Section 10. At the end of the article an appendix is given listing the symbols and units used.

2. INTRODUCTION.

Formulæ for coaxial cables are rather scattered among the literature on the subject and are not always given in the best form for rapid calculation and design. It was therefore found desirable to collect the fundamental formulæ given by Heaviside, Russell, Dwight and others and to produce new forms which, with the aid of curves, could be used for rapid calculations of the primary and secondary constants of coaxial cables.

3. CALCULATION OF THE RESISTANCE AND INDUCTANCE.

Note: The formulæ derived below give the resistance and inductance in absolute electromagnetic units per centimetre of axial length. To convert these quantities to practical units, i.e. ohms per mile length and henries per mile length, a multiplying constant K_1 must be introduced. The value of K_1 in each case is

$$K_1 = 5280 \times 12 \times 2{\cdot}54 \times 10^{-9}$$
$$= 0{\cdot}0001609344$$

If R and L represent respectively the total resistance and inductance per unit length we can write :—

$$R = R_c + R_s \quad \ldots\ldots (1)$$
$$L = L_a + L_c + L_s \quad \ldots\ldots (2)$$

where R_c = resistance per unit length associated with the power loss in the core.

R_s = resistance per unit length associated with the power loss in the sheath.

L_a = inductance per unit length associated with the magnetic field in the annular space.

L_c = inductance per unit length associated with the magnetic field in the core.

L_s = inductance per unit length associated with the magnetic field in the sheath.

3. 1. *Formulæ applicable at all frequencies and to any size of coaxial conductors with hollow or solid central cores.*

Referring to the cross-sectional diagram of the coaxial cable (see Fig. 1),

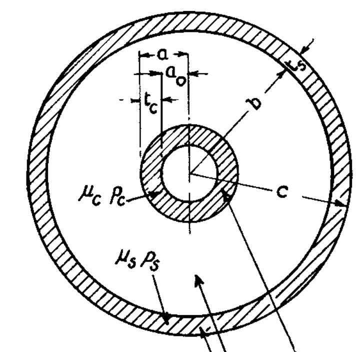


FIG. 1—CROSS SECTION OF COAXIAL CABLE.

---

[1] The quantity $\frac{\alpha}{\omega}$ has been called "phase delay" throughout. It is considered that this expression is better than the more usual one of "transmission time" for the following reasons :—

(a) It represents a "delay" rather than a true transmission time.

(b) The inverse quantity $\frac{\omega}{\alpha}$ is usually called the "phase velocity."

(c) The differential $\frac{d\alpha}{d\omega}$ is always called "differential, or envelope, delay," and not "differential transmission time."

let c = external radius of the sheath in cm.
b = internal radius of the sheath in cm.
a = external radius of the core in cm.
a_o = internal radius of the core in cm.

Then $L_a = 2\mu_a \log_\epsilon \frac{b}{a}$ ....(3)

where μ_a = permeability of the annular space

Now let $Z_c = R_c + j\omega L_c$ ....(4)

$Z_s = R_s + j\,\omega\,L_s$ ....(5)

where $\omega = 2\,\pi\,f$

and f = frequency in cycles per second.

Then

$$Z_c = \frac{j\,m_c\,\rho_c}{2\,\pi\,a} \cdot \left[\frac{(\text{ber } m_c a + j \text{ bei } m_c a) + \phi_c (\text{ker } m_c a + j \text{ kei } m_c a)}{(\text{ber}' m_c a + j \text{ bei}' m_c a) + \phi_c (\text{ker}' m_c a + j \text{ kei}' m_c a)}\right] \text{.(6)}$$

and

$$Z_s = \frac{-j m_s \rho_s}{2\,\pi\,b} \cdot \left[\frac{(\text{ber } m_s b + j \text{ bei } m_s b) + \phi_s (\text{ker } m_s b + j \text{ kei } m_s b)}{(\text{ber}' m_s b + j \text{ bei}' m_s b) + \phi_s (\text{ker}' m_s b + j \text{ kei } m_s b)}\right] \text{.(7)}$$

where $\phi_c = -\left[\frac{\text{ber}' m_c a_o + j \text{ bei}' m_c a_o}{\text{ker}' m_c a_o + j \text{ kei}' m_c a_o}\right]$

$\phi_s = -\left[\frac{\text{ber}' m_s c + j \text{ bei}' m_s c}{\text{ker}' m_s c + j \text{ kei}' m_s c}\right]$

ber, bei, ker, kei, etc., are Bessel functions

and $m_c = 2\sqrt{\frac{\pi\,\omega\mu_c}{\rho_c}}$ ....(8)

$m_s = 2\sqrt{\frac{\pi\,\omega\,\mu_s}{\rho_s}}$ ....(9)

ρ_c, ρ_s = resistivity in e.m.u. of the material of the inner and outer conductors respectively.

μ_c, μ_s = permeability of the material of the inner and outer conductors respectively.

Note :

For standard annealed copper at 20° C,
$\rho = 1724$ e.m.u.

For standard annealed copper at 60° F,
$\rho = 1697$ e.m.u.

For standard hard drawn copper at 20° C,
$\rho = 1773$ e.m.u.

From the expressions (6) and (7) Z_c and Z_s may be calculated for any type and size of coaxial conductors, at any frequency. The values of R_c, L_c, R_s and L_s can then be obtained by separating the real and imaginary parts of Z_c and Z_s respectively in equations (4) and (5), and the total resistance and inductance then follow from equations (1) and (2).

A table of Bessel functions of order zero is given by H. B. Dwight in " Bessel Functions for A.C. Problems," Trans. A.I.E.E., 1929, pp. 812-820.

3. 2. *Asymptotic formulæ applicable at high frequencies to coaxial cables having a hollow core and any thickness of wall in the core or sheath.*

The expressions given in equations (6) and (7) for Z_c and Z_s may also be written in the following form :

$$Z_c = \frac{j^{\frac{1}{2}}}{a}\sqrt{\frac{\omega\mu_c\rho_c}{\pi}} \cdot \left[\frac{I_o(m_c a j^{\frac{1}{2}})K_o'(m_c a_o j^{\frac{1}{2}}) - I_o'(m_c a_o j^{\frac{1}{2}})K_o(m_c a j^{\frac{1}{2}})}{I_o'(m_c a j^{\frac{1}{2}})K_o'(m_c a_o j^{\frac{1}{2}}) - I_o'(m_c a_o j^{\frac{1}{2}})K_o'(m_c a j^{\frac{1}{2}})}\right] \text{..(10)}$$

$$Z_s = \frac{-j^{\frac{1}{2}}}{b}\sqrt{\frac{\omega\mu_s\rho_s}{\pi}} \cdot \left[\frac{I_o(m_s b j^{\frac{1}{2}})K_o'(m_s c j^{\frac{1}{2}}) - I_o'(m_s c j^{\frac{1}{2}})K_o(m_s b j^{\frac{1}{2}})}{I_o'(m_s b j^{\frac{1}{2}})K_o'(m_s c j^{\frac{1}{2}}) - I_o'(m_s c j^{\frac{1}{2}})K_o'(m_s b j^{\frac{1}{2}})}\right] \text{....(11)}$$

The *asymptotic expansions* of the above expressions are :—

$$Z_c \sim \frac{(1+j)\sqrt{\frac{\omega\,\mu_c\rho_c}{2\,\pi}}}{a} \cdot \frac{1 + \epsilon^{-(1+j)h_c}}{1 - \epsilon^{-(1-j)h_c}} \text{ ....(12)}$$

$$Z_s \sim \frac{(1+j)\sqrt{\frac{\omega\,\mu_s\rho_s}{2\,\pi}}}{b} \cdot \frac{1 + \epsilon^{-(1+j)h_s}}{1 - \epsilon^{-(1+j)h_s}} \text{ ....(13)}$$

where $h_c = \sqrt{2}\,m_c\,(a - a_o)$ ....(14)

$h_s = \sqrt{2}\,m_s\,(c - b)$ ....(15)

These asymptotic expansions may be used providing $m_c a$ and $m_s b$ are each greater than about 5.

Now, the expression $\frac{1 + \epsilon^{-(1+j)h}}{1 - \epsilon^{-(1-j)h}}$

is equal to $\frac{\text{Sinh }(h) - j \text{ Sin }(h)}{\text{Cosh }(h) - \text{Cos }(h)}$

and therefore

$$Z_c = \frac{\sqrt{2}\,\omega\,\mu_c}{m_c\,a} \cdot \frac{[\text{Sinh }(h_c) + \text{Sin }(h_c)] + j\,[\text{Sinh }(h_c) - \text{Sin }(h_c)]}{\text{Cosh }(h_c) - \text{Cos }(h_c)} \text{ ....(16)}$$

$$Z_s = \frac{\sqrt{2}\,\omega\,\mu_s}{m_s\,b} \cdot \frac{[\text{Sinh }(h_s) + \text{Sin }(h_s)] + j\,[\text{Sinh }(h_s) - \text{Sin }(h_s)]}{\text{Cosh }(h_s) - \text{Cos }(h_s)} \text{ ....(17)}$$

Then, since $Z_c = R_c + j\,\omega\,L_c$
and $Z_s = R_s + j\,\omega\,L_s$

we have

$$R_c = \frac{\sqrt{2}\,\omega\,\mu_c}{m_c\,a}\,\frac{\text{Sinh }(h_c) + \text{Sin }(h_c)}{\text{Cosh }(h_c) - \text{Cos }(h_c)} \text{ ....(18)}$$

$$L_c = \frac{\sqrt{2}\,\mu_c}{m_c\,a}\,\frac{\text{Sinh }(h_c) - \text{Sin }(h_c)}{\text{Cosh }(h_c) - \text{Cos }(h_c)} \text{ ......(19)}$$

$$R_s = \frac{\sqrt{2}\,\omega\,\mu_s}{m_s\,b}\,\frac{\text{Sinh }(h_s) + \text{Sin }(h_s)}{\text{Cosh }(h_s) - \text{Cos }(h_s)} \text{ ....(20)}$$

$$L_s = \frac{\sqrt{2}\,\mu_s}{m_s\,b}\,\frac{\text{Sinh }(h_s) - \text{Sin }(h_s)}{\text{Cosh }(h_s) - \text{Cos }(h_s)} \text{ ......(21)}$$

Equations (18) to (21) may be used for all values of h_c and h_s providing $m_c a$ and $m_s b$ are each greater than about 5, i.e. at high frequencies.

The equations may be written in a more convenient form as follows :

$$R_c = \frac{\sqrt{2}\,\omega\,\mu_c}{m_c\,a} F_R(h_c) = \sqrt{\mu_c\rho_c f}\,\frac{F_R(h_c)}{a} \quad \ldots\ldots (22)$$

$$R_s = \frac{\sqrt{2}\,\omega\,\mu_s}{m_s\,b} F_R(h_s) = \sqrt{\mu_s\rho_s f}\,\frac{F_R(h_s)}{b} \quad \ldots\ldots (23)$$

$$\text{where } F_R(h) = \frac{\text{Sinh}(h) + \text{Sin}(h)}{\text{Cosh}(h) - \text{Cos}(h)} \quad \ldots\ldots\ldots\ldots\ldots (24)$$

$$\text{and } L_c = \frac{\sqrt{2}\,\mu_c}{m_c\,a}.F_L(h_c) = \frac{1}{2\pi}\sqrt{\frac{\mu_c\rho_c}{f}}.\frac{F_L(h_c)}{a} \ldots (25)$$

$$L_s = \frac{\sqrt{2}\,\mu_s}{m_s\,b}.F_L(h_s) = \frac{1}{2\pi}\sqrt{\frac{\mu_s\rho_s}{f}}.\frac{F_L(h_s)}{b} \ldots (26)$$

$$\text{where } F_L(h) = \frac{\text{Sinh}(h) - \text{Sin}(h)}{\text{Cosh}(h) - \text{Cos}(h)} \quad \ldots\ldots\ldots\ldots (27)$$

The complete expressions for the total resistance and total inductance at high frequencies of the coaxial cable with hollow central conductor are therefore :

$$R = \sqrt{2}\,\omega \left[\frac{\mu_c}{m_c a} F_R(h_c) + \frac{\mu_s}{m_s b} F_R(h_s)\right]$$

e.m.u. per cm. .... (28)

$$= \sqrt{f}\left[\sqrt{\mu_c\rho_c}\,\frac{F_R(h_c)}{a} + \sqrt{\mu_s\rho_s}\,\frac{F_R(h_s)}{b}\right]$$

.... (28a)

$\sqrt{\mu\,\rho} = 41{\cdot}2$ for standard annealed copper at 60°F.

$$L = 2\,\mu_a \log_\epsilon \frac{b}{a} + \sqrt{2}\left[\frac{\mu_c}{m_c a} F_L(h_c) + \frac{\mu_s}{m_s b} F_L(h_s)\right]$$

e.m.u./cm. .... (29)

$$= 2\,\mu_a \log_\epsilon \frac{b}{a} + \frac{1}{2\pi\sqrt{f}}.$$

$$\left[\sqrt{\mu_c\rho_c}\,\frac{F_L(h_c)}{a} + \sqrt{\mu_s\rho_s}\,\frac{F_L(h_s)}{b}\right] \ldots\ldots (29a)$$

These formulæ apply providing $m_c a$ and $m_s b$ are each greater than about 5. With copper conductors this is equivalent to f being greater than $535/a^2$ c.p.s.

The values of the functions F_R (h) and F_L (h), for values of " h " up to h=6, are shown graphically in Fig. 2. It will be seen from these curves that for any value of h greater than about 5, F_R (h) and F_L (h) approach very closely to unity.

F_R (h) is a minimum when $h=\pi$, the minimum value being 0·91714.

If $h_c = h_s = \pi$ we have

$$a - a_0 = \frac{1}{4}\sqrt{\frac{\rho_c}{\mu_c f}} \text{ and } c - b = \frac{1}{4}\sqrt{\frac{\rho_s}{\mu_s f}}$$

3\. 3. *Asymptotic formulæ applicable at high frequencies to the special case where the walls of the conductors are thick.*

In a coaxial cable with a solid central conductor and thick sheath, if the frequency is high enough for

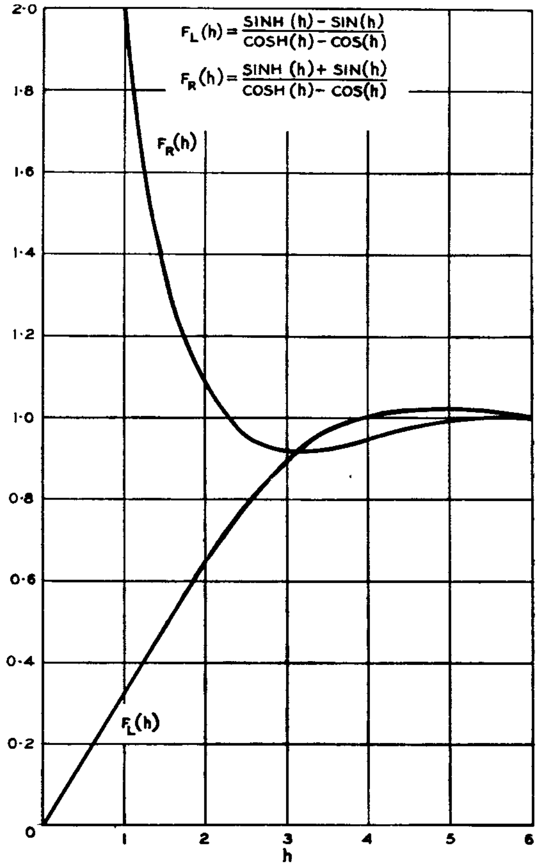


Fig. 2.—Values of $F_R(h)$ and $F_L(h)$.

h_c and h_s both to be greater than about 7, then equations (28) and (29) may be simplified as follows :

$$R = \sqrt{2}\,\omega\left[\frac{\mu_c}{m_c a} + \frac{\mu_s}{m_s b}\right] \text{ e.m.u. per cm.} \ldots (30)$$

$$= \sqrt{f}\left[\frac{1}{a}\sqrt{\rho_c\mu_c} + \frac{1}{b}\sqrt{\rho_s\mu_s}\right] \ldots\ldots (30a)$$

$$L = 2\,\mu_a \log_\epsilon \frac{b}{a} + \sqrt{2}\left[\frac{\mu_c}{m_c a} + \frac{\mu_s}{m_s b}\right]$$

e.m.u. per cm. .... (31)

$$= 2\,\mu_a \log_\epsilon \frac{b}{a} + \frac{R}{\omega}, \text{ R being in e.m.u. per cm.}$$

.... (31a)

4\. Calculation of the Capacitance.

If a =external radius of central conductor in cm.
b =internal radius of outer conductor in cm.
K_a =permittivity of the annular space,

then the capacitance of the coaxial cable in electrostatic units per cm. length is given by

$$C = \frac{1}{2}\,\frac{K_a}{\log_\epsilon \frac{b}{a}} \text{ e.s.u.}$$

Converting this to practical units, we have
Capacitance of cable in microfarads per mile

$$= \frac{K_a}{2 \log_\epsilon \frac{b}{a}} \times K_2 \quad \ldots\ldots (32)$$

where $K_2 = \frac{5280 \times 12 \times 2{\cdot}54}{9 \times 10^5}$

$= 0{\cdot}178816$

5. THE DERIVATION OF THE ATTENUATION CONSTANT, THE PHASE DELAY α/ω AND THE DIFFERENTIAL DELAY $d\alpha/d\omega$ FROM THE PRIMARY CONSTANTS OF THE CABLE (R, L, G AND C).

If R = resistance of the cable in ohms per mile
L = inductance of the cable in henries per mile
G = leakance of the cable in mhos per mile
C = capacitance of the cable in farads per mile
$\omega = 2\pi \times$ frequency in cycles per second.

Propagation constant

$$= \gamma$$
$$= \beta + j\alpha$$
$$= \sqrt{(R + j\omega L)(G + j\omega C)}$$
$$= j\omega\sqrt{LC}\sqrt{\left(1 + \frac{R}{j\omega L}\right)\left(1 + \frac{G}{j\omega C}\right)} \quad \ldots (33)$$

If $\frac{R}{\omega L}$ and $\frac{G}{\omega C}$ are small compared with unity this expression can be expanded to

$$\beta + j\alpha = \frac{R}{2}\sqrt{\frac{C}{L}} + \frac{G}{2}\sqrt{\frac{L}{C}} + j\omega\sqrt{LC} \cdot \left[1 + \frac{1}{8}\left(\frac{R}{\omega L} - \frac{G}{\omega C}\right)^2\right] \quad \ldots (34)$$

and hence:
Attenuation constant in nepers per mile

$$= \frac{R}{2}\sqrt{\frac{C}{L}} + \frac{G}{2}\sqrt{\frac{L}{C}} \quad \ldots\ldots (35)$$

The first part, representing the attenuation due to conductor loss, can be calculated from the formulæ given in Sections 3 and 4.

Phase constant in radians per mile

$$= \alpha$$
$$= \omega\sqrt{LC}\left[1 + \frac{1}{8}\left(\frac{R}{\omega L} - \frac{G}{\omega C}\right)^2\right] \quad \ldots\ldots (36)$$

Hence the *phase delay* in seconds per mile is:

$$\frac{\alpha}{\omega} = \sqrt{LC}\left[1 + \frac{1}{8}\left(\frac{R}{\omega L} - \frac{G}{\omega C}\right)^2\right] \quad \ldots\ldots (37)$$

R, L, G and C being in the practical units stated above.

$\frac{1}{\sqrt{LC}}$ = velocity of propagation along the cable in miles per second when the cable has zero loss.

$= V_0$ say, so that

$$\alpha = \frac{\omega}{V_0}\left[1 + \frac{1}{8}\left(\frac{R}{\omega L} - \frac{G}{\omega C}\right)^2\right] \quad \ldots\ldots (38)$$

and hence

$$\frac{d\alpha}{d\omega} = \frac{1}{V_0}\left[1 - \frac{1}{8}\left(\frac{R}{\omega L} - \frac{G}{\omega C}\right)^2\right] - \omega\left[1 + \frac{1}{8}\left(\frac{R}{\omega L} - \frac{G}{\omega C}\right)^2\right]\frac{\frac{dV_0}{d\omega}}{V_0^2} \quad \ldots (39)$$

Let $H = \frac{1}{8}\left(\frac{R}{\omega L} - \frac{G}{\omega C}\right)^2$ so that

$$\frac{d\alpha}{d\omega} = \frac{1}{V_0}\left[1 - H - (1 + H)\frac{\omega}{V_0}\frac{dV_0}{d\omega}\right]$$

Now $\frac{dV_0}{d\omega} = -\frac{1}{2}V_0\left[\frac{1}{L}\cdot\frac{dL}{d\omega} + \frac{1}{C}\cdot\frac{dC}{d\omega}\right]$

$$\therefore \frac{d\alpha}{d\omega} = \frac{1}{V_0}\left[1 - H + \frac{1}{2}(1 + H)\left(\frac{\omega}{L}\cdot\frac{dL}{d\omega} + \frac{\omega}{C}\cdot\frac{dC}{d\omega}\right)\right] \quad \ldots (40)$$

If $\frac{dL}{d\omega}$ is small compared with $\frac{L}{\omega}$

and $\frac{dC}{d\omega}$ is small compared with $\frac{C}{\omega}$

we may then write:
Differential delay in seconds per mile

$$= \frac{d\alpha}{d\omega} = \sqrt{LC}\left[1 - \frac{1}{8}\left(\frac{R}{\omega L} - \frac{G}{\omega C}\right)^2 + \frac{1}{2}\left\{\frac{\frac{dL}{d\omega}}{\frac{L}{\omega}} + \frac{\frac{dC}{d\omega}}{\frac{C}{\omega}}\right\}\right] \quad \ldots\ldots (41)$$

R, L, G and C being in the practical units stated above.

6. CALCULATION OF THE ATTENUATION.

6. 1. *Attenuation due to conductor loss.*

From eq. (35) we have:—

attenuation constant

$$\beta = \frac{R}{2}\sqrt{\frac{C}{L}} + \frac{G}{2}\sqrt{\frac{L}{C}} = \beta_m + \beta_d$$

Attenuation due to conductor loss =

$$\beta_m = \frac{R}{2}\sqrt{\frac{C}{L}} \text{ nepers per mile.}$$

R being in ohms, C in farads and L in henries per mile. If C is in farads per mile and L is in henries per mile

$$\sqrt{\frac{C}{L}} = \frac{1}{60 \log_\epsilon \frac{b}{a}}\sqrt{\frac{K_a}{\mu_a}}$$

to a very close degree of approximation.

6. 1. 1. *Asymptotic formulæ applicable at high frequencies to the special case where the walls of the conductors are thick.*

From eq. (30a) it may be shown that in this case the attenuation due to conductor loss

$$\beta_m = \frac{0{\cdot}00001165}{b}\sqrt{\frac{K_a f}{\mu_a}}\left[\frac{\frac{b}{a}\sqrt{\rho_c\,\mu_c}+\sqrt{\rho_s\,\mu_s}}{\log_\epsilon \frac{b}{a}}\right]$$

db. per mile ....(42)

It will be seen that in this case the attenuation is proportional to the square root of the frequency.

This formula applies providing $m_c a >$ about 5, and providing the thickness of the core is greater than $5/m_c$ and the sheath thickness greater than $5/m_s$. With copper conductors this is equivalent to f being greater than $535/a^2$ cycles and the wall thicknesses both greater than $23{\cdot}1/\sqrt{f}$ cms.

It is easily shown that for a given value of " b " this expression is a minimum when

$$\frac{b}{a}\left(\log_\epsilon \frac{b}{a} - 1\right) = \sqrt{\frac{\rho_s\,\mu_s}{\rho_c\,\mu_c}} \quad \ldots\ldots\ldots\ldots(42a)$$

$\frac{b}{a}\left(\log_\epsilon \frac{b}{a} - 1\right)$ is plotted against $\frac{b}{a}$ in Fig. **3**.

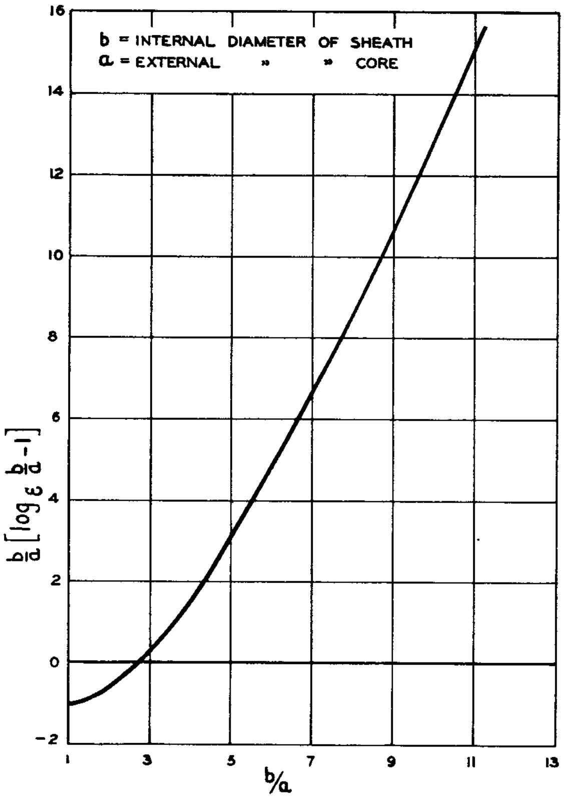


FIG. **3**.—CURVE FOR OBTAINING THE OPTIMUM RATIO OF SHEATH DIAMETER TO CORE DIAMETER FOR MINIMUM ATTENUATION.

From this graph the optimum value of b/a can be determined in any particular case. For the usual case where $\rho_s\,\mu_s = \rho_c\,\mu_c$ the optimum value of b/a for minimum attenuation is equal to 3·588.

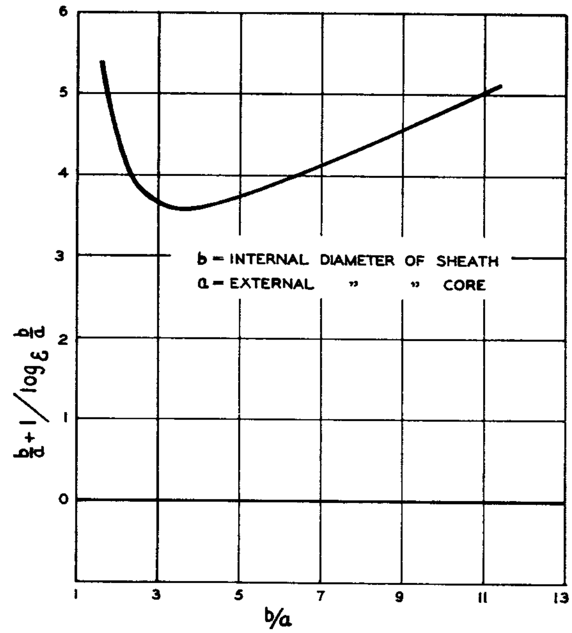


FIG. **4**.—CURVE SHOWING EFFECT OF VARIATION OF RATIO OF SHEATH TO CORE DIAMETER ON THE ATTENUATION AT HIGH FREQUENCIES OF A COAXIAL CABLE HAVING CONDUCTORS WITH THICK WALLS.

If the sheath is made of lead having a resistivity of 20,800 e.m.u. and the core is made of copper having a resistivity of 1,697 e.m.u., then the optimum value of b/a for minimum attentuation is 5·26.

The optimum value for the usual case where the core and sheath are of the same material, is not critical, as will be seen from Fig. **4**, where

$\dfrac{\frac{b}{a}+1}{\log_\epsilon \frac{b}{a}}$ is plotted as a function of $\frac{b}{a}$.

For copper conductors having a resistivity of 1,697 e.m.u., and the optimum ratio of b/a of 3,588, the attenuation due to conductor loss is given by

$$\beta_m = \frac{0{\cdot}001722}{b}\sqrt{\frac{K_a f}{\mu_a}} \text{ db. per mile} \ldots\ldots(43)$$

For a cable having a lead sheath and copper core having the resistivity mentioned above and the optimum ratio of b/a of 5·26, the attenuation due to conductor loss is given by

$$\beta_m = \frac{0{\cdot}002528}{b}\sqrt{\frac{K_a f}{\mu_a}} \text{ db. per mile} \ldots\ldots(44)$$

6. 1. 2. *Asymptotic formula applicable at high frequencies to coaxial cables having a hollow core and any thickness of wall in the core or sheath.*

In this case eq. (28a) gives :—
attenuation due to conductor loss

$$\beta_m = \frac{0{\cdot}00001165}{b}\sqrt{\frac{K_a f}{\mu_a}}\,.\left[\frac{\frac{b}{a}F_R(h_c)\sqrt{\rho_c\,\mu_c}+F_R(h_s)\sqrt{\rho_s\,\mu_s}}{\log_\epsilon \frac{b}{a}}\right] \text{ db. per mile} \ldots(45)$$

This formula applies to any wall thicknesses providing $m_c a$ and $m_s b$ are each greater than about 5. With copper conductors this is equivalent to "f" being greater than $535/a^2$ c.p.s.

$F_R(h_c)$ and $F^R(h_s)$ are independent of b/a, and therefore for given values of b, wall thickness and frequency, the optimum value of b/a for minimum attenuation is given by

$$\frac{b}{a}\left(\log_\epsilon \frac{b}{a} - 1\right) = \frac{F_R(h_s)}{F_R(h_c)} \sqrt{\frac{\rho_s \mu_s}{\rho_c \mu_c}} \quad \ldots\ldots\ldots (45a)$$

and the value of b/a in any case can be found from Fig. **3**. For the special case where the wall thicknesses are the same, and the materials of the core and sheath are the same, the optimum value of b/a for all frequencies is 3·588.

It was also seen in Section 3.2 that $F_R(h)$ is a minimum when $h = \pi$, the minimum value being 0·91714 (see Fig. **2**). It therefore follows that the attenuation will also be a minimum at a particular frequency when

$$h_c = h_s = \pi$$

$$\text{i.e., when } a - a_o = \frac{1}{4}\sqrt{\frac{\rho_c}{\mu_c f}},$$

$$\text{and } c - b = \frac{1}{4}\sqrt{\frac{\rho_s}{\mu_s f}}.$$

6. 2. *Formulæ applicable at high frequencies to four special types of cable.*

6. 2. 1. *Types of cable.*

The above formula for β_m applies at high frequencies to any thickness of walls in the core or sheath. In order to examine the design of cables with thin walls it is proposed to consider four special types of cable which will be designated A, B, C and D.

If the maximum frequency which it is required to transmit on the cable is f_2 and the values of h_c and h_s at this frequency are h_{c_2} and h_{s_2}, then in the first three types of cable specified below, the attenuation will be a minimum when h_{c_2} or h_{s_2} or both are equal to π, according to the type of cable. It will be assumed that both conductors are made of copper having a resistivity of 1,697 e.m.u., and that the frequency is greater than $535/a^2$ cycles. By a thick core or sheath is meant one in which the thickness exceeds about $23/\sqrt{f}$.

Type A. Copper conductors. Equal thicknesses of wall in the core and sheath.

$$\text{i.e. } t_c = t_s = t_{cs} \text{ say}$$
$$h_c = h_s = h_{cs} \text{ say}$$

In this type of cable the attenuation will always be a minimum when

$$\frac{b}{a} = 3{\cdot}588$$

and this value of b/a will always be used.

The attenuation at the maximum frequency f_2 will also be a minimum when

$$h_{cs_2} = \pi$$

$$\text{i.e. when } t_c = t_s = t_{cs} = \frac{10{\cdot}30}{\sqrt{f_2}} \text{ cm.}$$

Type B. Copper conductors. Thick sheath ($mh_s > 5$) *and core wall of any thickness.*

In this type of cable the attenuation at the maximum frequency f_2 is a minimum when

$$h_{c_2} = \pi$$

$$\text{i.e. when } t_c = \frac{10{\cdot}30}{\sqrt{f_2}} \text{ cm.}$$

The optimum value of b/a for minimum attenuation is then 3·67.

If the thickness of the core is other than that given above the optimum value of b/a will differ slightly from this figure, but as the optimum value of b/a is not critical the value 3·67 will be taken for this general type of cable.

Type C. Copper conductors. Thick core ($mh_c > 5$) *and sheath wall of any thickness.*

In this type of cable the attenuation at the maximum frequency f_2 is a minimum when

$$h_{s_2} = \pi$$

$$\text{i.e. when } t_s = \frac{10{\cdot}30}{\sqrt{f_2}} \text{ cm.}$$

The optimum value of b/a for minimum attenuation is then 3·52.

If the thickness of the sheath is other than that given above the optimum value of b/a will differ slightly from this figure, but as the best value of b/a is not critical the value 3·52 will be taken for this general type of cable.

Type D. Copper conductors. Thick core and sheath (mh_c *and* mh_s *both* > 5).

The attenuation of this type is a minimum when $b/a = 3{\cdot}588$, and this figure will be used.

6. 2. 2. *Attenuation formulæ for these four special types of cable (A, B, C and D).*

For the four special types of cable specified above we have, from equation (45),

$$\beta_m = \frac{0{\cdot}00564}{bt}\sqrt{\frac{K_a}{\mu_a}}\, M(h) \text{ db. per mile} \quad \ldots (46)$$

$$\text{where } h = 0{\cdot}3052\, t\sqrt{f} \quad \ldots\ldots\ldots\ldots\ldots\ldots (47)$$

The values of "t" and M (h) for the four types of cable are given below.

Type	*t*	*M (h)*
A	t_{cs}	$M_A(h_{cs}) = h_{cs}\, F_R(h_{cs})$
B	t_c	$M_B(h_c) = h_c\,[0{\cdot}786\, F_R(h_c) + 0{\cdot}214]$
C	t_s	$M_C(h_s) = h_s\,[0{\cdot}779 + 0{\cdot}221\, F_R(h_s)]$
D	t_{cs}	$M_D(h_{cs}) = h_{cs}$

The values of the function M (h) for the four different types are shown plotted against h^2 in Fig. **5**.

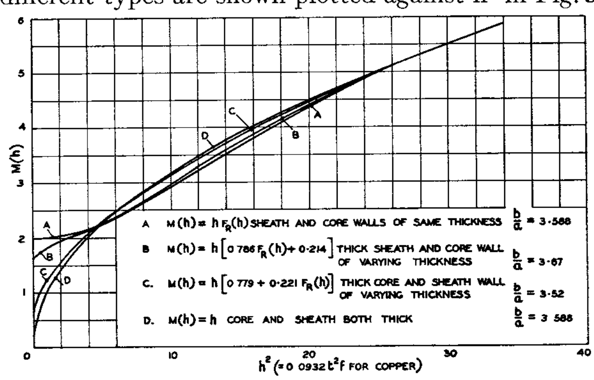


FIG. 5.—CURVES FOR DETERMINATION OF ATTENUATION CHARACTERISTICS OF FOUR SPECIAL TYPES OF COAXIAL CABLE WITH COPPER CONDUCTORS.

The horizontal scale in this drawing is proportional to frequency and hence the four curves outline the attenuation-frequency characteristic obtained with these four types of cable. The actual characteristics for any particular wall thickness and radius "b" can be rapidly determined from these curves.

All the above formulæ only apply providing

$$f > \text{about } \frac{6900}{b^2} \text{ c.p.s.}$$

6. 3. *Attenuation due to dielectric loss.*

It has been seen in equation (35) that the attenuation due to dielectric loss at high frequencies is given by

$$\frac{G}{2}\sqrt{\frac{L}{C}} \text{ nepers per mile}$$

G being in mhos, L in henries and C in farads, per mile.

Now $G = \omega C p$

where p = power factor of the dielectric,

∴ attenuation due to dielectric loss

$$= \frac{\omega p}{2}\sqrt{LC} \text{ nepers per mile.}$$

Putting L in henries per mile and C in farads per mile

$\sqrt{LC} = 5{\cdot}364 \times 10^{-6}\sqrt{K_a \mu_a}$ very nearly and the attenuation due to dielectric loss

$$= 23{\cdot}30 \times 10^{-6}\,\omega p\,\sqrt{K_a \mu_a} \text{ db. per mile} \quad \dots\dots (48)$$

7. Calculation of the Phase Delay $\frac{\alpha}{\omega}$

7. 1. *Asymptotic formula applicable at high frequencies to the special case where the walls of the conductor are thick.*

It has been seen that for a cable of this type

$$C = \frac{K_a}{2\log_\epsilon \frac{b}{a}} \times K_2 \times 10^6 \text{ farads per mile}$$

$$\text{and } L = K_1\left[2\,\mu_a \log_\epsilon \frac{b}{a} + \sqrt{2}\left(\frac{\mu_c}{m_c a} + \frac{\mu_s}{m_s b}\right)\right] \text{ henries per mile.}$$

Substituting

$$2\sqrt{\frac{\pi\,\omega\mu_c}{\rho_c}} = m_c \text{ from (8)}$$

$$\text{and } 2\sqrt{\frac{\pi\,\omega\mu_s}{\rho_s}} = m_s \text{ from (9)}$$

and putting

$$A = \frac{1}{2\,\mu_a \log_\epsilon \frac{b}{a}}\sqrt{\frac{1}{2\,\pi}}\left[\frac{\sqrt{\mu_c\rho_c}}{a} + \frac{\sqrt{\mu_s\rho_s}}{b}\right]$$

we have

$$L = 2K_1\,\mu_a \log_\epsilon \frac{b}{a}\left[1 + \frac{A}{\sqrt{\omega}}\right] \text{ henries per mile.} \quad (49)$$

Now, substituting in eq. (37) the values of L and C from eqs. (49) and (32)

$$\frac{\alpha}{\omega} = \sqrt{\mu_a K_a K_1 K_2}\left[1 + \frac{1}{8}\left(\frac{R}{\omega L} - \frac{G^2}{\omega C}\right)\right]\left[1 + \frac{A}{\sqrt{\omega}}\right]^{\frac{1}{2}} \times 10^{-3} \text{ seconds per mile} \quad \dots (50)$$

At high frequencies the terms $\frac{1}{8}\left(\frac{R}{\omega L} - \frac{G}{\omega C}\right)^2$ and $\frac{A}{\sqrt{\omega}}$ are both very small compared with unity, and therefore we can write,

$$\frac{\alpha}{\omega} = \sqrt{\mu_a K_a K_1 K_2}\left[1 + \frac{1}{8}\left(\frac{R}{\omega L} - \frac{G}{\omega C}\right)^2 + \frac{1}{4\mu_a \log_\epsilon \frac{b}{a}}\sqrt{\frac{1}{2\pi\omega}}\left(\frac{\sqrt{\mu_c\rho_c}}{a} + \frac{\sqrt{\mu_s\rho_s}}{b}\right)\right] \times 10^{-3}$$

seconds per mile .... (51)

$$\sqrt{K_1 K_2} = 0{\cdot}0053645$$

This expression is obviously closely related to the expression for the attenuation due to conductor loss given in eq. (42), and from this equation we obtain :—

$$\frac{\alpha}{\omega} = 5{\cdot}3645 \times 10^{-6}\sqrt{\mu_a K_a}\cdot\left[1 + \frac{1}{8}\left(\frac{R}{\omega L} - \frac{G}{\omega C}\right)^2 + \frac{3415\,\beta_m}{f}\cdot\frac{1}{\sqrt{\mu_a K_a}}\right]$$

seconds per mile .... (52)

where β_m = attenuation due to conductor loss in db. per mile.

Generally $\frac{1}{8}\left(\frac{R}{\omega L} - \frac{G^2}{\omega C}\right)$ is a second order quantity compared with the last term in the square brackets, so that to a fairly close degree of approximation,

$$\frac{\alpha}{\omega} = 5{\cdot}3645 \times 10^{-6}\sqrt{K_a \mu_a} + \frac{18320 \times 10^{-6}\,\beta_m}{f}$$

seconds per mile .... (53)

If the suffix 1 denotes values at frequency f_1 and the suffix 2 denotes values at frequency f_2 then

$$\left(\frac{\alpha}{\omega}\right)_1 - \left(\frac{\alpha}{\omega}\right)_2 = 18320 \times 10^{-6}\left[\frac{\beta_{m1}}{f_1} - \frac{\beta_{m2}}{f_2}\right]$$

seconds per mile .... (54)

This equation is very important in connection with television transmission on coaxial cables having thick walled conductors. It shows that with this type of cable the difference in the phase delay at two frequencies f_1 and f_2 increases in proportion to the attenuation due to conductor loss. It therefore follows that the only method of reducing the difference in phase delay with this type of cable is to increase the diameter of the cable so as to reduce the conductor loss, unless the permeability of the annular space could be increased without additional loss. This can also be seen directly from eq. (42). This matter is considered further in Section 7.4.

7. 2. *Asymptotic formulæ applicable at high frequencies to coaxial cables having hollow cores and any thickness of wall in the core or sheath.*

For a coaxial cable with a hollow central conductor we have from eq. (29a),

$$L = 2\,\mu_a K_1 \log_\epsilon \frac{b}{a}\,.$$

$$\left[1 + \frac{1}{2\mu_a \log_\epsilon \frac{b}{a}}\sqrt{\frac{1}{2\pi\omega}}\left\{\frac{\sqrt{\mu_c\rho_c}}{a}F_L(h_c) + \frac{\sqrt{\mu_s\rho_s}}{b}F_L(h_s)\right\}\right]$$

henries per mile .... (55)

and hence substituting for L and C in eq. (37).

$$\frac{\alpha}{\omega} = \sqrt{\mu_a K_a K_1 K_2}\left[1 + \frac{1}{8}\left(\frac{R}{\omega L} - \frac{G}{\omega C}\right)^2 + \frac{1}{4\mu_a \log_\epsilon \frac{b}{a}}\sqrt{\frac{1}{2\pi\omega}}\left\{\frac{\sqrt{\mu_c\rho_c}}{a}F_L(h_c) + \frac{\sqrt{\mu_s\rho_s}}{b}F_L(h_s)\right\}\right]$$

$\times 10^{-3}$ seconds per mile .... (56)

$$\sqrt{K_1 K_2} = 0{\cdot}0053645.$$

This formula applies providing $m_c a$ and $m_s b$ are each greater than about 5.

For copper conductors having a resistivity of 1697 e.m.u. this equation becomes

$$\frac{\alpha}{\omega} = 5{\cdot}36 \times 10^{-6}\sqrt{K_a\mu_a}\left[1 + \frac{1}{8}\left(\frac{R}{\omega L} - \frac{G}{\omega C}\right)^2 + \frac{1{\cdot}640}{b\log_\epsilon \frac{b}{a}}\cdot\frac{1}{\sqrt{f}}\left\{\frac{b}{a}F_L(h_c) + F_L(h_s)\right\}\right] \text{seconds per mile} \ldots (57)$$

$h_c = 0{\cdot}3052\, t_c \sqrt{f}$ from equation (14)

$h_s = 0{\cdot}3052\, t_s \sqrt{f}$ from equation (15)

Eq. (57) can be used for values of frequency exceeding $535/a^2$ c.p.s.

7. 3. *Asymptototic formulæ applicable at high frequencies to four special types of coaxial cable (A, B, C and D).*

In section 6.2.1. four special types of coaxial cable, designated A, B, C and D were described and formulæ for the attenuation of these cables were given in Section 6.2.2.

From equation (57) it may be shown that for these special types

$$\frac{\alpha}{\omega} = 5{\cdot}36 \times 10^{-6}\sqrt{K_a\mu_a}\left[1 + \frac{1}{8}\left(\frac{R}{\omega L} - \frac{G}{\omega C}\right)^2 + \frac{1{\cdot}800\,t}{b}\,.\,N(h)\right] \text{seconds per mile} \ldots\ldots\ldots (58)$$

where $h = 0{\cdot}3052\, t\sqrt{f}$ .... (59)

The values of "t" and N (h) for the four types of cable are given below.

Type	*t*	*N (h)*
A	t_{cs}	$N_A(h_{cs}) = \frac{1}{h_{cs}} F_L(h_{cs})$
B	t_c	$N_B(h_c) = \frac{1}{h_c}\left[0{\cdot}786\, F_L(h_c) + 0{\cdot}214\right]$
C	t_s	$N_C(h_s) = \frac{1}{h_s}\left[0{\cdot}779 + 0{\cdot}221\, F_L(h_s)\right]$
D	t_{cs}	$N_D(h_{cs}) = \frac{1}{h_{cs}}$

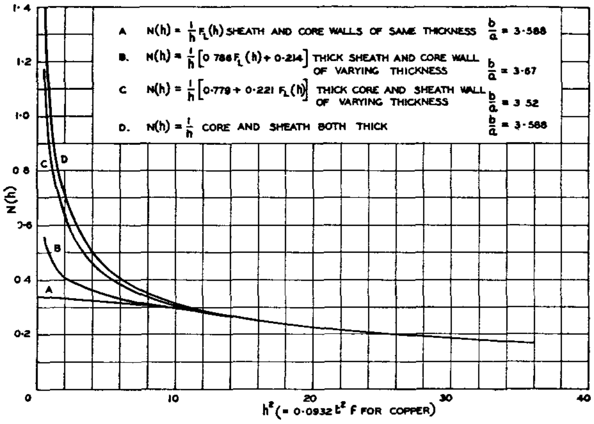


FIG. 6.—CURVES FOR DETERMINATION OF PHASE DELAY CHARACTERISTICS FOR SPECIAL TYPES OF COAXIAL CABLES WITH COPPER CONDUCTORS.

$N_A(h)$, $N_B(h)$, $N_C(h)$ and $N_D(h)$ are plotted as functions of h^2 (i.e. as functions of frequency for a given wall thickness) in Figs. **6** and **7**. These curves show the type of phase delay—frequency characteristic obtained with these four types of cable, and the actual characteristic for any particular wall thickness and radius "b" can be determined from them.

The above formulæ can only be used providing

$$f > \text{about } \frac{6900}{b^2} \text{ c.p.s.}$$

It may be shown that

$$\frac{R}{\omega L} = \frac{4{\cdot}29 \times 10^4}{\sqrt{K_a\,\mu_a}}\cdot\frac{\beta_m}{\omega} \ldots\ldots\ldots\ldots\ldots (60)$$

to a close approximation in all cases, β_m being in db. per mile.

$\dfrac{G}{\omega C} = p$, the power factor of the dielectric.

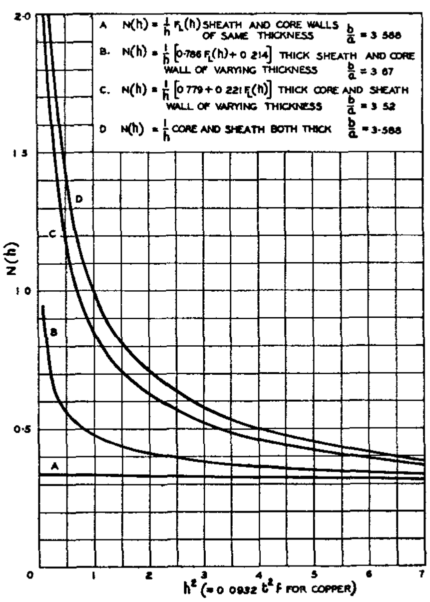


FIG. 7.—CURVES FOR DETERMINATION OF PHASE DELAY CHARACTERISTICS FOR SPECIAL TYPES OF COAXIAL CABLE WITH COPPER CONDUCTORS.

It will be found in nearly all cases that

$\frac{1}{8}\left(\frac{R}{\omega L} - \frac{G}{\omega C}\right)^2$ is small compared with

$\frac{1 \cdot 800\ t}{b} N(h)$ and it can usually be neglected.

When necessary it is easily determined from equation (60) above and the equations given in Section 6.1 for β_m.

7. 4. *Difference in the phase delay at frequency f_1 and frequency f_2 in the four special types of coaxial cable described in Section 6.2.1.*

In television transmission it is desirable to know the difference in the phase delay between the maximum and minimum frequencies of the transmission band occupied by the signals on the cable.

Let f_1 = minimum frequency

f_2 = maximum frequency

$\frac{f_2}{f_1} = r$

Then, from equation (58),

$$\left(\frac{\alpha}{\omega}\right)_1 - \left(\frac{\alpha}{\omega}\right)_2 = \frac{9 \cdot 63 \times 10^{-6} t}{b} \sqrt{K_a \mu_a} \left[N(h_1) - N(h_2)\right]$$

seconds per mile........................(61)

the suffix 1 denoting values at frequency f_1 and the suffix 2 denoting values at frequency f_2

Now $h_1 = 0 \cdot 3052\ t \sqrt{f_1}$

$h_2 = 0 \cdot 3052\ t \sqrt{f_2}$

$$\therefore \frac{h_2}{h_1} = \sqrt{\frac{f_2}{f_1}} = \sqrt{r}$$

$$\therefore h_1 = \frac{h_2}{\sqrt{r}}$$

$$\left(\frac{\alpha}{\omega}\right)_1 - \left(\frac{\alpha}{\omega}\right)_2 = \frac{9 \cdot 63 \times 10^{-6} t}{b} \sqrt{K_a \mu_a} \left[N\left(\frac{h_2}{\sqrt{r}}\right) - N(h_2)\right]$$

$$= \frac{9 \cdot 63 \times 10^{-6} t}{b} \sqrt{K_a \mu_a}\ .F(r, h_2)$$

seconds per mile........................(61a)

where $F(r, h_2) = N\left(\frac{h_2}{\sqrt{r}}\right) - N(h_2)$ ....(61b)

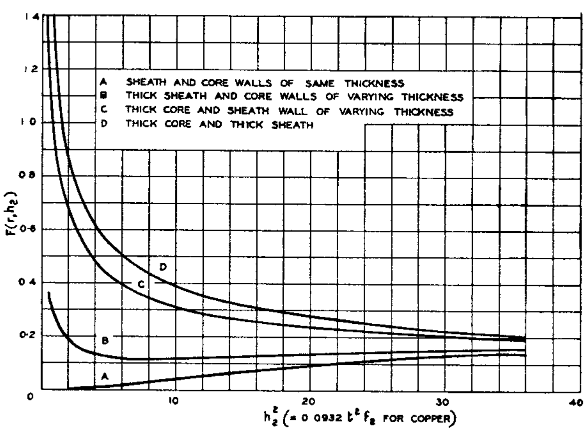


FIG. 8.—CURVES OF F (r, h_2), WHEN $r = \frac{f_2}{f_1} = 5$

This function is plotted against $(h_2)^2$, for various values of "r" for the four special types of cable, in Figs. **8**, **9** and **10**.

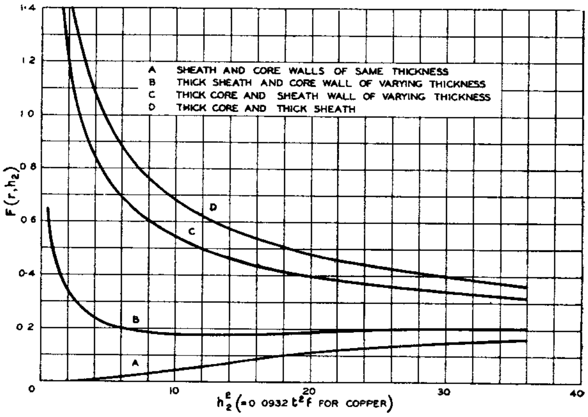


FIG. **9**.—CURVES OF F(r, h_2), WHEN $r = \frac{f_2}{f_1} = 10$.

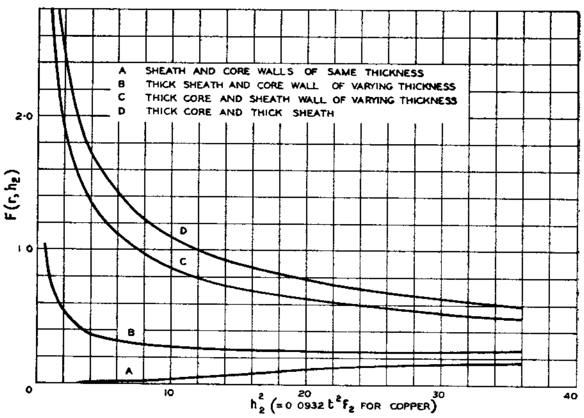


FIG. **10**.—CURVES OF F(r, h_2), WHEN $r = \frac{f_2}{f_1} = 20$.

8. CALCULATION OF THE DIFFERENTIAL DELAY $\left(\frac{d\alpha}{d\omega}\right)$

8. 1. *Asymptotic formula applicable at high frequencies to the special case where the walls of the conductors are thick.*

Consider equation (41) which gives the differential delay in seconds per mile.

From equation (49) we have

$$\frac{dL}{d\omega} = -2\mu_a K_1 \left(\log_\epsilon \frac{b}{a}\right) \frac{A}{2}\ \omega^{-\frac{3}{2}} \quad ....(62)$$

and therefore, as $A/\sqrt{\omega}$ is very small at high frequencies,

$$\frac{\frac{dL}{d\omega}}{\frac{L}{\omega}} = -\frac{A}{2\sqrt{\omega}} \text{ very nearly} \quad ....(63)$$

Also, from equation (32), if K_a is assumed to be independent of frequency,

$\frac{dC}{d\omega}$ will be zero.

Therefore, equation (41) now becomes

$$\frac{d\alpha}{d\omega} = \sqrt{LC}\left[1-\frac{1}{8}\left(\frac{R}{\omega L}-\frac{G}{\omega C}\right)^2-\frac{A}{4\sqrt{\omega}}\right] \quad \ldots(64)$$

and inserting the values of L and C from equations (31) and (32),

$$\frac{d\alpha}{d\omega}= \sqrt{\mu_a K_a K_1 K_2}\left[1-\frac{1}{8}\left(\frac{R}{\omega L}-\frac{G}{\omega C}\right)^2 + \frac{1}{8\mu_a \log_\epsilon\frac{b}{a}}\sqrt{\frac{1}{2\pi\omega}}\left(\frac{\sqrt{\mu_c\rho_c}}{a}+\frac{\sqrt{\mu_s\rho_s}}{b}\right)\right]\times 10^{-3}$$

seconds per mile. . . . (65)

$$\sqrt{K_1K_2} = 0{\cdot}0053645$$

Eq. (65) is applicable providing $m_c a$ and $m_s b$ are each greater than about 5, and h_c and h_s are each greater than about $5\sqrt{2}$.

8. 2. *Asymptotic formulæ applicable at high frequencies to coaxial cables having a hollow core and any thickness of wall in the core or sheath.*

If $\frac{dC}{d\omega}$ is zero,

$$\frac{d\alpha}{d\omega} = \sqrt{LC}\left[1-\frac{1}{8}\left(\frac{R}{\omega L}-\frac{G}{\omega C}\right)^2+\frac{1}{2}\frac{\frac{dL}{d\omega}}{\frac{L}{\omega}}\right] \quad ..(66)$$

and on inserting the values of L and C from equations (29) and (32) this becomes

$$\frac{d\alpha}{d\omega} = \sqrt{\mu_a K_a K_1 K_2}\left[1-\frac{1}{8}\left(\frac{R}{\omega L}-\frac{G}{\omega C}\right)^2 + \frac{1}{4\mu_a \log_\epsilon\frac{b}{a}}\sqrt{\frac{1}{2\pi\omega}}\left\{\frac{\sqrt{\mu_c\rho_c}}{a}F_L(h_c)+\frac{\sqrt{\mu_s\rho_s}}{b}F_L(h_s)\right\} + \frac{1}{2}\frac{\frac{dL}{d\omega}}{\frac{L}{\omega}}\right]\times 10^{-3} \text{ seconds per mile} \ldots (67)$$

$$\sqrt{K_1K_2} = 0{\cdot}0053645$$

R being in ohms per mile
L being in henries per mile
G beings in mhos per mile and
C being in farads per mile.

Eq. (67) applies providing $m_c a$ and $m_s b$ are each greater than about 5.

The above is found to be the most convenient form of the formula for the theoretical determination of $d\alpha/d\omega$.

The term $\frac{dL/d\omega}{L/\omega}$ is calculated separately as follows :—

From equation (2),

$$\frac{dL}{d\omega} = \frac{dL_a}{d\omega}+\frac{dL_c}{d\omega}+\frac{dL_s}{d\omega}$$

and since $\frac{dL_a}{d\omega} = 0$,

$$\frac{dL}{d\omega} = \frac{dL_c}{d\omega}+\frac{dL_s}{d\omega} \quad \ldots\ldots\ldots\ldots\ldots(68)$$

Now $L_c = \frac{\sqrt{2}\,\mu_c}{m_c a}F_L(h_c)$ from equation (25)

$$\therefore \frac{dL_c}{d\omega} = \frac{dL_c}{dm_c}\cdot\frac{dm_c}{d\omega}$$

$$= \frac{dm_c}{d\omega}\cdot\frac{\sqrt{2}\,\mu_c}{a}\cdot\frac{m_c\frac{d}{dm_c}F_L(h_c)-F_L(h_c)}{m_c^2} \quad \ldots\ldots\ldots\ldots(69)$$

As $m_c = 2\sqrt{\frac{\pi\omega\mu_c}{\rho_c}}$

we have

$$\frac{dm_c}{d\omega} = \frac{m_c}{2\omega} \quad \ldots\ldots\ldots\ldots\ldots(70)$$

Also,

$$\frac{d}{dm_c}F_L(h_c) = \frac{d}{dh_c}F_L(h_c)\times\frac{dh_c}{dm_c}$$

From equation (27),

$$\frac{d}{dh_c}F_L(h_c) = \frac{2.\left[1-\cos(h_c)\cosh(h_c)\right]}{\left[\cosh(h_c)-\cos(h_c)\right]^2} \quad \ldots\ldots\ldots(71)$$

and from equation (14)

$$\frac{dh_c}{dm_c} = \frac{h_c}{m_c} \quad \ldots\ldots\ldots\ldots\ldots(72)$$

Hence, substituting in equation (69),

$$\frac{dL_c}{d\omega} = \frac{m_c\sqrt{2}\,\mu_c}{2\omega\, a\, m_c^2}\left\{\frac{2h_c\left[1-\cos(h_c)\cosh(h_c)\right]}{\left[\cosh(h_c)-\cos(h_c)\right]^2}-F_L(h_c)\right\}$$

$$= \frac{\sqrt{2}\,\mu_c}{\omega m_c a}\cdot\frac{h_c\left[1-\cos(h_c)\cosh(h_c)\right]}{\left[\cosh(h_c)-\cos(h_c)\right]^2}-\frac{L_c}{2\omega} \quad ..(73)$$

Writing $G(h) = \frac{h\left[1-\cos(h)\cosh(h)\right]}{\left[\cosh(h)-\cos(h)\right]^2}$ . . . . .(74)

we have

$$\frac{dL_c}{d\omega} = \frac{\sqrt{2}\,\mu_c}{\omega\, m_c a}\cdot G(h_c) - \frac{L_c}{2\omega}$$

and similarly

$$\frac{dL_s}{d\omega} = \frac{\sqrt{2}\,\mu_s}{\omega\, m_s b}\cdot G(h_s) - \frac{L_s}{2\omega}$$

$$\therefore \frac{dL}{d\omega} = \frac{\sqrt{2}}{\omega}\left[\frac{\mu_c}{m_c a}G(h_c)+\frac{\mu_s}{m_s b}G(h_s)\right]-\frac{1}{2\omega}(L_c+L_s) \quad \ldots\ldots\ldots(75)$$

and hence

$$\frac{\frac{dL}{d\omega}}{\frac{L}{\omega}} = \frac{\sqrt{2}}{L}\left[\frac{\mu_c}{m_c a}G(h_c)+\frac{\mu_s}{m_s b}(G(h_s))\right] - \frac{1}{2}\left[1-\frac{2\mu_a\log_\epsilon\frac{b}{a}}{L}\right] \quad \ldots\ldots\ldots(76)$$

It should be noted that the value of L used in equation (76) is to be expressed in e.m.u. per cm.

Fig. **11** indicates values of the function G (h) for values of h up to h = 6. Beyond this point G (h) decreases quickly to a very small value.

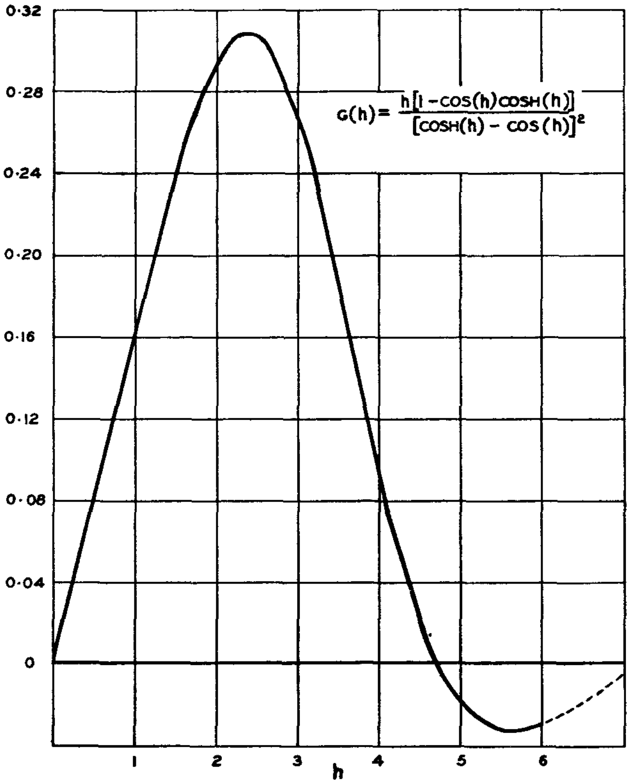


FIG. 11.—VALUES OF G(h).

9. DESIGN OF COAXIAL CABLES FROM THE POINT OF VIEW OF ATTENUATION CHARACTERISTIC ONLY.

The design will be based on the following data which will be assumed to be known :—

(1) Material of the conductors.

(2) Properties of the dielectric.

(3) Frequency band f_1 to f_2 over which it is proposed to transmit on the cable.

(4) Attenuation at the maximum frequency f_2.

(5) Desired shape of the attenuation characteristic, if any limitations are to be placed on this.

It will be assumed that, at present, the cable is required only for carrier telephony, so that the variation of phase delay with frequency need not be considered. The design when this has to be taken into account is dealt with in Section **10**.

For the dielectric we know the permittivity K_a, permeability μ_a and power factor at frequency f_2, namely p_2. Hence the attenuation due to dielectric loss at the highest frequency f_2 is from equation (48) given by

$$\beta_{d2} = 23{\cdot}30 \times 10^{-6}\, \omega_2\, p_2 \sqrt{K_a \mu_a} \text{ db. per mile.}$$

The total attenuation at frequency f_2 will be assumed to be given equal to β_2 db. per mile. The attenuation due to conductor loss at frequency f_2 is therefore

$$\beta_{m2} = \beta_2 - \beta_{d2} \text{ db. per mile.}$$

The problem may now be divided into two cases :—

(1) Where there is no limitation on the shape of the attenuation frequency characteristic in the frequency range f_1 to f_2.

(2) Where the shape of the attenuation frequency characteristic in the frequency range f_1 to f_2 is to follow as far as possible a predetermined form.

9. 1. *Method of design when no limitation is imposed on the shape of the attenuation frequency characteristic.*

Case No. 1. When the walls of both conductors may be thin. The best possible design from the point of view of obtaining the minimum possible attenuation for a given overall diameter is to make :—

$$\frac{b}{a} = 3{\cdot}588$$

$$t_c = \frac{1}{4}\sqrt{\frac{\rho_c}{\mu_c f_2}} \text{ cm.} \qquad t_s = \frac{1}{4}\sqrt{\frac{\rho_s}{\mu_s f_2}} \text{ cm.}$$

and $h_{c_2} = h_{s_2} = \pi = h_{cs_2}$.

If the conductors are both of copper,

$$t_c = t_s = \frac{10{\cdot}3}{\sqrt{f_2}} \text{ cm.}$$

This becomes a special case of Type A cable described in Section **6.2.1**, and from equations (46) and (47) we obtain :

$$b = \frac{0{\cdot}001578}{\beta_{m2}}\sqrt{\frac{K_a f_2}{\mu_a}} \text{ cm.} \qquad \text{............(77)}$$

The attenuation characteristic may be determined directly from equation (46) and M_A (h) in Fig. **5**, remembering that $(h_{cs_2})^2 = \pi^2$.

Case No. 2. When the sheath has to be thick and the wall of the core can be thin.

In this case make

$$t_c = \frac{1}{4}\sqrt{\frac{\rho_c}{\mu_c f_2}} \text{ cm.}$$

$$h_{c_2} = \pi$$

$$F_B\,(h_{c_2}) = 0{\cdot}9171$$

The optimum value of b/a for conductors of the same material is then given by equation (45a) and is

$$\frac{b}{a} = 3{\cdot}67$$

For copper conductors this becomes a special case of Type B cable described in Section **6.2.1**, and from equations (46) and (47) we obtain

$$b = \frac{0{\cdot}001614}{\beta_{m2}}\sqrt{\frac{K_a f_2}{\mu_a}} \text{ cm.} \qquad \text{..............(78)}$$

It will be seen that this is only **2·2** per cent. greater than in Case No. **1**. The attenuation characteristic may be obtained from equation (46) and M_B (h) in Fig. **5**, remembering that $(h_{c_2})^2 = \pi^2$.

Case No. 3. When the core is solid and the sheath is thin.

In this case make

$$t_s = \frac{1}{4}\sqrt{\frac{\rho_s}{\mu_s f_2}} \text{ cm.}$$

$$h_{s_2} = \pi$$

$$F_B\,(h_{s_2}) = 0{\cdot}9171$$

The optimum value of b/a for conductors of the same material is then given by equation (45a) and is

$$\frac{b}{a} = 3{\cdot}52$$

For copper conductors this becomes a special case of Type C cable described in Section 6.2.1, and from equations (46) and (47) we obtain

$$b = \frac{0{\cdot}001688}{\beta_{m2}} \sqrt{\frac{K_a f_2}{\mu_a}} \text{ cm.} \quad \ldots\ldots\ldots\ldots (79)$$

It will be seen that this is 7 per cent. greater than in Case No. 1. The attenuation characteristic may be obtained from equation (46) and M_c (h) in Fig. **5**, remembering that $(h_{s2})^2 = \pi^2$.

Case No. 4. Solid core and thick sheath.

In this case the optimum value of b/a is 3·588.

For copper conductors,

$$\beta_m = \frac{0{\cdot}001722}{b} \sqrt{\frac{K_a f}{\mu_a}} \text{ db. per mile} \quad \ldots . (80)$$

This is a special case of Type D cable described in Section 6.2.1. The value of " b " is given by

$$b = \frac{0{\cdot}001722}{\beta_{m2}} \sqrt{\frac{K_a f_2}{\mu_a}} \text{ cm.} \quad \ldots\ldots\ldots\ldots (81)$$

This is 9·1 per cent. greater than in Case No. 1.

9.2. *Method of design when the shape of the attenuation frequency characteristic between the frequencies f_1 and f_2 is to follow, as far as possible, a predetermined form.*

If the thickness of the walls of both conductors is large, the attenuation is proportional to the square root of the frequency at high frequencies. If, however, the wall of either one or both conductors can be made thin, then it is possible to obtain some control over the shape of the attenuation frequency characteristic in the desired transmission band. The various shapes that are possible with the four special types of cable A, B, C and D have been examined in Section 6.2.2. The type giving the nearest approach to the desired characteristic can be chosen, and the value of " h " at the frequency f_2 is then determined by the part of the characteristic which most nearly fits the desired form. The thickness of the walls is then fixed and the value of " b " can be determined as before from β_{m2}.

9.3. *General conclusion with regard to design from point of view of attenuation.*

The above formulæ show that, unless it is desired to obtain a special form of attenuation frequency characteristic, there is not much to be gained in attenuation by using thin walls in the conductors It will be seen in Section 10, however, that there is a good deal to be gained from the point of view of phase delay.

10. Design of Coaxial Cables When Phase Delay is to be Taken into Account in Addition to Attenuation.

The data on which the design will be based will be the same as that given at the beginning of Section 9 with the exception that no limitation will be placed on the shape of the attenuation characteristic. Further the maximum and minimum frequencies and the difference in phase delay between these two frequencies will be assumed to be given.

Only the four special types of coaxial cable A, B, C and D described in Section 6.2.1 will be considered here. These cover practically the whole range of possible types having solid copper walls and the consideration of intermediate types can be carried out, if necessary, using the more general formulæ given in Sections 6.1.2. and 7.2.

For each of these four types we have from equations (46) and(47) :—

$$\beta_{m2} = \frac{0{\cdot}00564}{bt} \sqrt{\frac{K_a}{\mu_a}} M(h_2) \text{ db. per mile} \ldots . (82)$$

$$\text{and} \quad h_2 = 0{\cdot}3052\, t \sqrt{f_2} \quad \ldots\ldots\ldots\ldots\ldots\ldots (83)$$

From equations (82) and (83) we can plot " b " against " t " for the given attenuation β_{m2} at frequency f_2, obtaining M (h_2) from Fig. **5**.

From equations (61a) and (61b) we also have

$$\left(\frac{\alpha}{\omega}\right)_1 - \left(\frac{\alpha}{\omega}\right)_2 = \frac{9{\cdot}63 \times 10^{-6} t}{b} \sqrt{K_a \mu_a} F(r, h_2)$$

$$\text{seconds per mile} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (84)$$

$F(r,h_2)$ may be obtained from equation (61b) and the N(h) functions shown in Figs. **6** and **7** or if r = 5, 10 or 20 it may be obtained directly from Figs. **8**, **9** or **10**.

Hence, using equation (84) and knowing b, t and r, we can find $(\alpha/\omega)_1 - (\alpha/\omega)_2$.

It is therefore possible, with given values of β_{m2} and r, to plot " b " and $(\alpha/\omega)_1 - (\alpha/\omega)_2$. against " t " for any of the four types of cable. If a definite value is assigned to $(\alpha/\omega)_1 - (\alpha/\omega)_2$ then the value of " b " is fixed for any particular type of cable.

Using the design data and curves already given, an example has been worked out for

f_2 =2,500 kc.p.s.
r = 5, i.e. f_1 = 500 kc.p.s.
β_{m2} = 5 db. per mile.

the values of " K_a " and " μ_a " being taken as unity.

Fig. **12** shows " b " and $(\alpha/\omega)_1 - (\alpha/\omega)_2$ plotted against " t " for the four special types of cable considered, using the above values of f_2, r and β_{m2}.

From these curves the following very interesting and useful conclusions may be drawn (for the particular example worked out, the attenuation at the maximum frequency being fixed) :—

(1) A decrease in the variation of phase delay over the transmission band may be obtained by the use of thin-walled conductors without appreciable change in the internal radius of the sheath required.

(2) If for mechanical or other reasons the sheath only can be made thin, it being necessary to use a solid core, then it is only possible to reduce the variation of phase delay in the transmission band to about 79 per cent. of the value obtained when both walls are thick, without increasing the internal radius of the sheath.

(3) If only the core wall can be made thin, it being necessary to maintain a thick wall in the sheath for

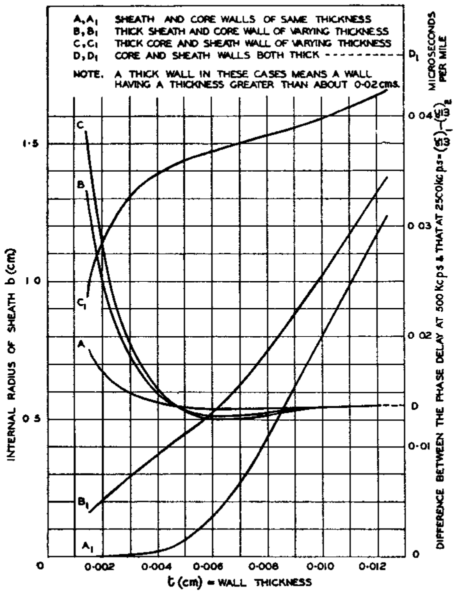


FIG. 12.—CURVES SHOWING "b" (CURVES A, B AND C) AND $\left(\frac{\alpha}{\omega}\right)_1 - \left(\frac{\alpha}{\omega}\right)_2$ (CURVES A_1, B_1 AND C_1) FOR A COAXIAL CABLE WITH f_2 = 2,500 KC.P.S.
r = 5, i.e. frequency band = 500 KC.P.S. TO 2,500 KC.P.S.
β_{m_2} = 5db PER MILE = ATTENUATION AT 2,500 KC.P.S.

mechanical reasons or for good electro-magnetic shielding, then it is possible to reduce the variation of phase delay in the transmission band to about 25 per cent. of the value obtained when both walls are thick, without increasing the internal radius of the sheath.

(4) If both walls can be made thin then it is possible to reduce the variations of phase delay in the transmission band to about 3·3 per cent. of the value obtained when both walls are thick, without increasing the internal radius of the sheath, or to about 0·5 per cent. with an increase of only 6 per cent. in this radius.

The above conclusions only apply strictly to the example considered, but they apply in a general way to other similar cases.

It is very interesting to note that, in the particular example considered, if both walls are given a thickness of 0.003 cm, and the internal radius of the sheath is 0·6 cm, then the difference between the phase delay at 500 kc.p.s. and that at 2,500 kc.p.s. is only about 0·025 micro-second for 100 miles of cable. Such a cable would be practically ideal for television transmission; in fact it seems probable that no phase correction would be necessary for the cable even on 400 miles of cable, if the 0 to 2,000 kc.p.s. frequency spectrum of the television signals were first raised by 500 kc.p.s. before transmitting on the cable.

The attenuation-frequency curve of such a cable is practically flat, the attenuation being 4.95 db. per mile as 500 kc.p.s. and 5.00 db per mile at 2,500 kc.p.s. The resistance is 113.1 ohms per mile at 2,500 kc.p.s. and 111·6 ohms per mile to direct current.

With a cable having similar dimensions but thick walls in the core and sheath, the maximum length over which no phase correction would be necessary for the same type of transmission (i.e. 500 kc.p.s. to 2,500 kc.p.s.) would only be about two miles.

A very considerable improvement in the variation in phase delay is possible by using only a thin-walled core, retaining the thick sheath, as indicated in conclusion No. 3 above.

Practical methods of plating thin-walled conductors on insulating materials such as hard rubber may be found. It is also possible that the advantages of thin walls may be obtained by plating copper on high resistance materials such as iron. A theoretical examination of this latter method would be very complex, but would yield results of practical value.

The exact extent to which it is desirable to reduce the phase delay to less than that obtained on coaxial cables having thick walls (e.g. the London-Birmingham cable) is still uncertain until the problem of designing networks to correct this variation has been fully studied. When this has been done the relative merits of thin-walled conductors and of thick-walled conductors with attenuation and phase equalising circuits can be compared. One advantage of the thin walled conductors is, however, already apparent. The attenuation and phase characteristics of thick walled conductors vary appreciably with temperature, and on a long cable it is necessary to vary the equalisation as the temperature of the cable varies. With thin-walled conductors the attenuation would have a temperature coefficient equal to that of the resistivity of the material, but the attenuation characteristic would remain the same, i.e. flat. This would simplify automatic gain control. Since it is unlikely that phase equalisation would be required with thin walls, there would be no problem of varying this equalisation with temperature, as with the thick-walled cable.

11. CONCLUSION.

In conclusion, the authors wish to express their thanks to Mr. H. J. Josephs, of the Research Branch of the Engineer-in-Chief's Office, for his assistance in connection with the original formulæ given in Section 3 from which the practical design formulæ have been developed.

APPENDIX

LIST OF SYMBOLS (Including Units)

1. CABLE DIMENSIONS (see Fig. 1).

c = external radius of the sheath in cm.
b = internal radius of the sheath in cm.
t_s = radial thickness of the sheath in cm.
a = external radius of the core in cm.
a_0 = internal radius of the core in cm.
t_c = radial thickness of the core in c.m.
t = general term for thickness of the core or sheath.

2. PROPERTIES OF CONDUCTOR AND DIELECTRIC MATERIALS.

ρ_c = resistivity of the core material in e.m.u.

ρ_s = resistivity of the sheath material in e.m.u.
μ_c = permeability of the core material.
μ_s = permeability of the sheath material.
μ_a = permeability of the annular space.
K_a = permittivity of the annular space.
p = power factor of the annular space.

3. Resistance, Inductance, Leakage, Capacitance and Impedance per Unit Length.

R = total resistance in e.m.u. per cm. unless stated to be in ohms per mile in a particular case under consideration.
R_c = resistance associated with the power loss in the core, in e.m.u. per cm.
R_s = resistance associated with the power loss in the sheath, in e.m.u. per cm.
L = total inductance in e.m.u. per cm., unless stated to be in henries per mile in a particular formula.
L_a = inductance associated with the magnetic field in the annular space, in e.m.u. per cm.
L_c = inductance associated with the magnetic field in the core, in e.m.u. per cm.
L_s = inductance associated with the magnetic field in the sheath, in e.m.u. per cm.
Z_c = $R_c + j\omega L_c$ in e.m.u.
Z_s = $R_s + j\omega L_s$ in e.m.u.
C = capacitance in e.s.u. per cm., unless stated to be in farads per mile in the particular case under consideration.
G = leakance in mhos per mile.

4. Propagation Properties.

γ = propagation constant in nepers per mile.
β = attenuation constant in nepers per mile unless specifically stated to be in db. per mile.
β_m = part of β due to conductor loss.
β_d = part of β due to dielectric loss.
α = phase constant in radians per mile.
$\frac{\alpha}{\omega}$ = phase delay in seconds per mile.
V_o = velocity of transmission in the absecnce of losses, in miles per second.
$\frac{d\alpha}{d\omega}$ = differential delay in seconds per mile.
β_{m1} = value of β_m at frequency f_1.
β_{m2} = value of β_m at frequency f_2.

5. Factors for Transforming Absolute Units into Practical Units.

K_1 = 0·0001609344.
= multiplying factor to convert absolute e.m.u. of resistance or inductance per cm. into ohms or henries per mile respectively.
K_2 = 0·178816
= multiplying factor to convert e.s.u. per cm. into microfarads per mile.
$\sqrt{K_1 K_2}$ = 0·0053645.

6. Miscellaneous.

f = frequency in cycles per second.
ω = $2\pi f$ radians per second.

$$\phi_c = -\left[\frac{\text{ber}'\, m_c a_o + j\,\text{bei}'\, m_c a_o}{\text{ker}'\, m_c a_o + j\,\text{kei}'\, m_c a_o}\right]$$

$$\phi_s = -\left[\frac{\text{ber}'\, m_s c + j\,\text{bei}'\, m_s c}{\text{ker}'\, m_s c + j\,\text{kei}'\, m_s c}\right]$$

$$m_c = 2\sqrt{\frac{\pi\,\omega\,\mu_c}{\rho_c}}$$

$$m_s = 2\sqrt{\frac{\pi\,\omega\,\mu_s}{\rho_s}}$$

$$h_c = \sqrt{2}\, m_c (a - a_o) = \sqrt{2}\, m_c t_c$$

$$h_s = \sqrt{2}\, m_s (c - b) = \sqrt{2}\, m_s t_s$$

$$F_R(h) = \frac{\sinh(h) + \sin(h)}{\cosh(h) - \cos(h)}$$
(see Fig. **2**)

$$F_L(h) = \frac{\sinh(h) - \sin(h)}{\cosh(h) - \cos(h)}$$
(see Fig. **2**)

$$G(h) = \frac{h\,[1 - \cos(h)\cosh(h)]}{[\cosh(h) - \cos(h)]^2}$$
(see Fig. **11**)

$$H = \frac{1}{8}\left[\frac{R}{\omega L} - \frac{G}{\omega C}\right]^2$$

$$A = \frac{1}{2\mu_a \log_\epsilon \frac{b}{a}}\sqrt{\frac{1}{2\pi}}\left[\frac{\sqrt{\mu_c \rho_c}}{a} + \frac{\sqrt{\mu_s \rho_s}}{b}\right]$$

$M_A(h) = h\, F_R(h)$
$M_B(h) = h\,(0.786\, F_R(h) + 0{\cdot}214)$
$M_C(h) = h\,(0{\cdot}779 + 0{\cdot}221\, F_R(h))$
$M_D(h) = h$
(see Fig. **5**)

$$N_A(h) = \frac{1}{h} F_L(h)$$

$$N_B(h) = \frac{1}{h}\left[0{\cdot}786\, F_L(h) + 0{\cdot}214\right]$$

$$N_c(h) = \frac{1}{h}\left[0{\cdot}779 + 0{\cdot}221\, F_L(h)\right]$$

$$N_D(h) = \frac{1}{h}$$
(see Figs. **6** and **7**)

$$F(r, h_2) = N\left(\frac{h_2}{\sqrt{r}}\right) - N(h_2)$$
(see Figs. **8**, **9** and **10**)

$$r = \frac{f_2}{f_1}$$

f_1 = minimum frequency in transmission band.
f_2 = maximum frequency in transmission band.

Direct Underground Distribution in Residential Areas

D. W. CHERRY and H. BROOK

The authors discuss the factors necessary for the economical provision of direct underground distribution, and describe in detail a method which has been employed to serve a typical estate.

Introduction.

DIRECT underground distribution to subscribers' premises is comparatively rare in residential areas outside London. When a new estate is being developed it has been usual to serve the first few subscribers by an overhead route. At a later date a duct track connecting to overhead distribution poles (D.P.'s) may be required, by which time in all probability the footways have been made up and relatively expensive reinstatement charges are incurred. This underground route caters for future growth, but a number of overhead wires will already have been erected and must now be recovered, thus involving a considerable wastage in plant and labour. At a later stage it may be found that the telephone density has reached a figure which would have justified direct underground distribution had the growth been foreseen and the estate layout known. It is difficult to justify a complete re-arrangement when a fairly satisfactory system of overhead distribution already exists.

The methods described above have often been inevitable in the past. Subscribers must be given service without delay, while the compilation of reliable development forecasts, the preparation of estimates and the letting of contracts for duct work all take a considerable time.

Direct Underground Distribution.

The present rapid development of the telephone service occurring simultaneously with building development may often make it practicable for new estates to be served by direct underground distribution, but it must be emphasised that its economical introduction depends as much upon good organisation as on the application of new engineering methods.

Advantages.

The advantages of underground distribution are well known, but may be recapitulated as follows:

(*a*) Improved service due to a reduction in the number of faults.

(*b*) Reduction in maintenance costs.

(*c*) Elimination of storm damage. In addition to the direct cost, storm work causes serious dislocation of the normal routine of the Section causing delay in construction works and in the provision of new lines.

(*d*) Wayleave difficulties are reduced.

(*e*) The amenities of the district are conserved.

Cost.

In sparsely telephoned areas overhead distribution is the only method which can be economically employed. Again, where large detached houses, set well back from the footway, are concerned, the cost of a complete underground system is prohibitive in spite of the high telephone density. In favourable circumstances, however, the provision of underground leads-in can be justified.

The principal factors which influence favourably the cost of underground distribution are:

(*a*) The avoidance of re-instatement charges by laying the ducts and the lead-in pipes before the footways and road are made up. The lead-in pipes are often not laid until service is required, but this is not economical owing to the reinstatement charges involved and the high labour charges on discontinuous work of this nature. It is safe to assume that with the type of property for which underground distribution would be considered, every house would at some time or other be telephoned so that there is no saving of stores by postponing the work.

(*b*) The presence of a grass verge in which the "main" track can be situated so that split couplings can be used at the jointing points instead of surface boxes.

(*c*) Semi-detached houses so that one lead-in serves two subscribers.

(*d*) Short front gardens, so reducing the length of the lead-in.

(*e*) An anticipated high telephone density.

(*f*) The facilities necessary to carry out the work before service is required so that no temporary overhead construction is necessary.

(*g*) In the event of overhead construction being the cheaper method the builder may be willing to defray the additional cost of underground distribution or else to provide the labour for the trenching work and to lay a wrought-iron pipe for the lead-in cable from the street to the house.

Items of underground stores such as 3-in. self-aligning ducts, surface boxes and split couplings, were designed for general purposes, including use with large cables, and are expensive. On self-contained estates, however, cables are small, and there is a need for a small robust duct which is cheap and can be laid at shallow depth. A $1\frac{1}{2}$-in. asbestos cement duct is being considered for this purpose in the Engineer-in-Chief's office. Consideration is also being given to the possibility of providing a light armoured cable which will be laid direct in the ground.

Flexibility.

The increase in the number of lines for an exchange area can be forecast, but for a block of, say, 20 houses, a reliable estimate cannot be given. Even if an accurate average figure is given for this small block, the actual number of lines will fluctuate about this mean figure. The larger the block, however, the more closely will the actual number approximate to the average. It is desirable, therefore, to obtain flexibility of plant over as large an area as possible.

In overhead distribution there are three methods of obtaining flexibility:

(*a*) That due to the open wires themselves, i.e. any house in the D.P. area can be connected to any pair terminated on the terminal block.

(*b*) Teeing.

(*c*) Auxiliary joints.

With underground distribution some method of obtaining the facility (*a*) above must be used, while some form of distribution point such as a block terminal must exist before (*a*), (*b*) and (*c*) can be employed. Every house could be connected direct to the main frame in the first instance. Unfortunately, new estates are generally a considerable distance from the exchange, and even at " saturation " some 20 per cent. of the pairs would be spare although each pair would be used at some period or other. Quite apart from economic considerations, owing to the demands now being made on the underground system, such wastage could not be countenanced on an extensive scale. Each house can be led back to a key joint where any spare pair can be picked up as required, thus giving complete flexibility. This joint can be situated so as to be the distribution point for, say, 50-100 houses, thus meeting the requirement that flexibility could be obtainable over a large area. This method, however, is considered to be not entirely satisfactory, as the paper insulation on quad local cables is not very robust and joints will not stand constant handling. An auxiliary joint is not a satisfactory comparison, as the joints are only opened up occasionally for the general redistribution of spare pairs and not for the provision of service to individual subscribers. An alternative method of obtaining flexibility as applied to a particular estate is described later in the article.

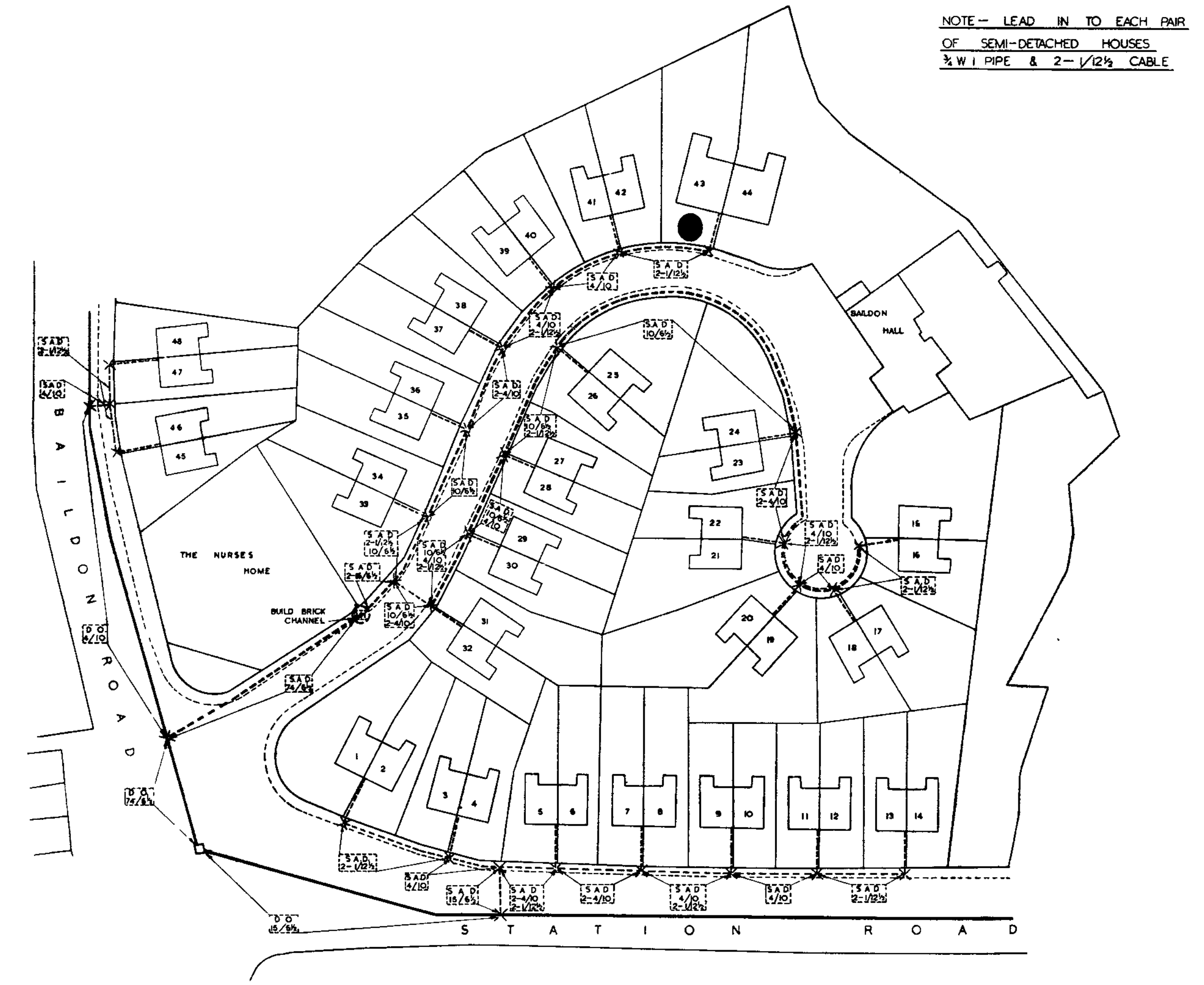


FIG. 1—LAYOUT OF THE ESTATE.

Fault Liability.

If the leads-in are only provided when service is required the " main " cable must be opened up frequently with the resultant liability that interruptions may be caused to working circuits. In addition, the work is not done under such careful supervision as if the work had been carried out as a whole, and unless care is taken the insulation of the cable will fall below standard.

Joints are a source of weakness and in laying out a distribution scheme the number of jointing points should be kept at a minimum, while the system should be as straightforward as possible owing to the difficulty of maintaining accurate records.

Novel Features of the Method of Underground Distribution Used on a New Estate.

The application of the principles discussed above can best be shown by describing the system of distribution employed in a particular case The layout of the estate is shown in Fig. **1**. The conditions favourable for underground distribution were :

(*a*) The builder supplied the layout plans of the estate, the cost of the houses, etc., so enabling the development to be forecast accurately, and detailed estimates prepared at an early date. It was therefore possible to lay the "main" duct track and the leads-in, in conjunction with the road operations and in advance of the permanent surfacing.

(*b*) The houses are semi-detached.

(*c*) The leads-in are only 10 yards.

(*d*) There is a grass verge so split couplings were used at the jointing points.

(*e*) The anticipated telephone density is 90 per cent. within two years. As the houses are fairly small this figure requires some explanation. Calculated on the rateable value basis, under normal conditions, the anticipated density in 14 years would be 33 per cent. The builder, however, paid the 15s. connection charge for each house, the condition being that the houses were wired during their construction. The first occupier was relieved of this charge and increased sales were therefore anticipated. During the first twelve months, 85 per cent. of the occupiers have become subscribers, so that the high figure was justified.

(*f*) The plant was provided before service was required.

A comparison between the cost of overhead and underground leads-in was made and it was found that the underground system was the cheaper.

Duct Work.

The most economical way of serving the main part of the estate would have been to take a duct track through the centre on private property and feed the houses from the back. This, however, was not done owing to the undesirability of having underground plant on private property unless a wayleave in perpetuity can be obtained. Alternatively, a track could have been laid along one footway of the cul-de-sac with a feed across the road for each pair of houses. The road was not made up at the time of laying, but in the event of a fault at a crossing expensive reinstatement charges would have been incurred. In addition, long lengths of 2-pair cable would have been required, and this was undesirable as this cable is not of very strong construction. It was decided therefore to lay a track down each side of the central road. As only small cables were involved and it was extremely improbable that it would be necessary to draw over at a later date, the use of wood troughing was considered, but owing to their longer life and lower annual charges self-aligning ducts were used.

For leading-in $\frac{3}{4}$-in. wrought-iron pipes were decided upon. These provide ample accommodation and can be laid at shallow depth. In suitable circumstances the pipes could be fixed to the dividing fence above the ground level. The pipes were connected to the main track by means of split couplings No. 17 and pipes C.I. reducing No. 1.

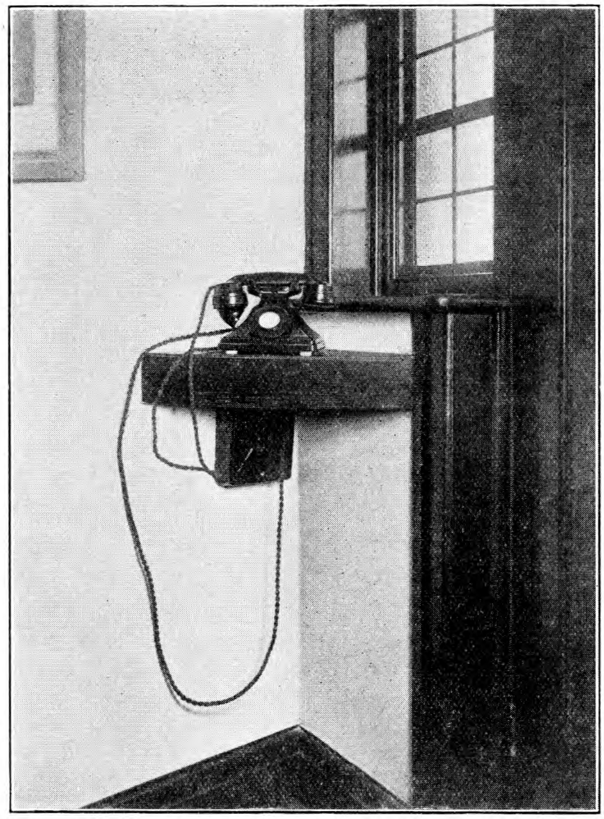


Fig. **2**.—Telephone and Directory Shelf.

Cabling.

At the subscriber's end the leads-in were run under the floor, so avoiding unsightly wiring on the outside walls. The builder was asked to fit a telephone and directory shelf in the hall (Fig. **2**). It was thought that the subscribers would then agree to the telephone being fitted in this position. This would avoid the necessity of having to extend the lead-in at a later date or, alternatively, of leaving the cable loose with the possibility of its getting damaged. The builder agreed to this proposal and the leads were cleated into position, and terminal blocks (blocks terminal No. 1) fitted. Up to the present, every subscriber has made use of the shelf and no alterations have been necessary.

The number of joints in the external cabling was kept to a minimum by taking back four 1-pr./12½ leads until a common joint could be made. Normally it is undesirable to have 1-pr./12½ leads in a duct track owing to the possibility of damage when drawing over additional cable at a later date, but when, as in this case, it is certain that no additional cable will be required, there is no objection. As compared with general practice this layout saves a joint between two 1-pr. leads and a 2-pr. cable at each pair of houses and a joint in the main cable outside every other pair of houses.

Flexibility.

The estate is situated 1½ miles from the exchange, so that it was uneconomical to connect every house to the exchange. In addition, growth in this area had been particularly rapid and some form of flexibility had to be provided so as to keep to a minimum the number of pairs required between the estate and the exchange.

Owing to the disadvantages of a " key joint," which have already been discussed, it was decided to provide a distribution frame on the estate. Existing items of stores had to be used as service was required at an early date. To house the " frame " a " Pillar, Group Service No. 1 " was used. This is made damp-proof by means of rubber bearing surfaces for the inspection doors, and was found to be quite suitable for the purpose. On one side of the " frame " it was necessary to provide pairs to every house, and on the other sufficient to meet the maximum requirements at any period. The line from any house could then be jumpered to any spare pair to the exchange. In the limited space available the most suitable method of terminating the cables in the pillar was on " blocks terminal No. 16," each of which accommodates 15 pairs. The layout is shown in Fig. **3**. Fifteen pair

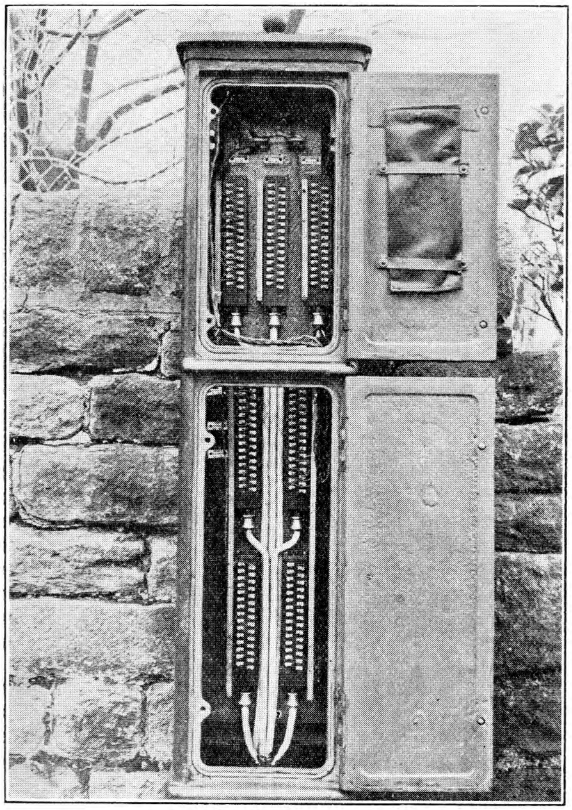


FIG. **3**.—STREET PILLAR.

cables were led through thimbles to each block, the wires laced out, soldered connections made and the back of the block flooded with paraffin wax. Owing to the limited amount of space it was not possible to joint these 15 pair " tails " to the main cables inside the pillar itself. The joints were made in a brick chamber at the foot of the pillar and need never be opened again. The cables enter the pillar via a hole in a removable plate in the base, and after the cables were in position the plate was replaced and the base flooded with paraffin wax, so obtaining a damp-proof pillar. Seven terminal blocks were mounted on wooden back-boards. This provides for terminating 105 pairs, although only 90 were required in this instance. In a general case, however, 60 houses and 45 exchange lines could be accommodated, so providing for a telephone density of 75 per cent., although, of course, any other percentage could be obtained by suitably arranging the joints in the brick chamber. For making the cross connections wire E. and F.P. was used and run via rings provided at the side of the pillar. Owing to the temporary shortage of plant only 35 exchange pairs were connected to the pillar, but these sufficed until relief could be given.

In an individual case the number of pairs saved by introducing flexibility may appear to be small, but as the use of underground distribution increases the saving is considerable.

This method of providing flexibility is admittedly expensive due to the fact that existing stores items were used. Headquarters' consideration is being given to the provision of a less expensive fitting to give the same facilities.

Records.

The plant records for the pillar were provided on a plan basis. A copy of Fig. **1**, together with the plan, are kept in the pillar, at the exchange and at the advice note control. The plot numbers as shown in Fig. **1** are used for reference instead of the postal addresses. The pair numbers for the distribution pillar are the block terminal pair numbers.

Provision of Service and Maintenance.

With overhead distribution a 4-man gang or 2-man party is necessary to provide service for a new subscriber. With the normal method of underground distribution a gang or contractor is required to lay the lead-in pipe, a jointer and mate to find a spare pair to the exchange and connect up the lead-in, and a fitter to install the telephone. With the method of distribution described above, however, only one man, the fitter, is required. He installs the telephone and runs the jumper at the distribution pillar, and service can be given the same day as the advice note is received. In the event of a pair to the exchange becoming faulty the line can be changed over by the instrument faultsman and service is restored without the aid of a jointer.

The system has been working for a year and has been entirely satisfactory. No trouble has been experienced due to low insulation in the distribution pillar in spite of its having been frequently opened in wet weather. When subscribers' lines were tested with a 250 volt megger from the terminal blocks (blocks terminal No. 1) to the exchange, the insulation was found to be above megger range.

Conclusion.

The items of stores used are not ideal, but service was required at short notice and existing items of stores had to be used. The system gives an economical and efficient service with a low fault liability. A simple form of flexibility is provided, new subscribers can be connected with the minimum delay, while service can readily be restored on faulty lines.

Notes and Comments

Coronation Honours List

We offer our congratulations to all members of the Post Office Staff mentioned in the Coronation Honours List. We were pleased to note that the Director-General, Sir Thomas Gardiner, K.B.E. had been made a Knight Commander of the Most Honorable Order of the Bath and that the Engineering Department had been honoured by the award of the Imperial Service Order to Mr. J. W. Atkinson, Deputy Regional Director, North Eastern Region, and the Medal of the Most Excellent Order of the British Empire to Mr. R. C. Laughton, S.W.I, Edinburgh.

Institution of Electrical Engineers

A history of the Institution of Electrical Engineers is being written by Mr. Rollo Appleyard. A great deal of relevant material is already in the archives of the Institution, but it is felt that there must be many members of the Institution and others who have in their possession information, or can recall facts which might be of assistance to Mr. Appleyard in making the work complete so far as possible. The Council of the Institution has requested that those who have such information will write to Mr. Appleyard, at the office of the Institution of Electrical Engineers, Savoy Place, London, W.C.2.

The Coronation Broadcast

The B.B.C. earned the praise of the whole nation by its magnificent broadcast of the Coronation and the procession. To the Post Office Engineering Dept. comes a certain amount of reflected glory in that it was responsible in no small measure for the success of the Coronation arrangements. An extensive network of lines for the sound and television broadcasts was required, and, in addition, a multitude of other circuits for miscellaneous purposes. Some idea of the magnitude of the arrangements will be gathered from the article published in this issue.

The Post Office Convention

At the time of going to press the second Post Office Telecommunications Convention is in full session at The Hayes, Swanwick, Derbyshire.

The opening ceremony took place on Saturday, 12th June, when the Director-General, Sir Thomas Gardiner, K.C.B., K.B.E., with Lady Gardiner and Mr. and Mrs. B. O. Anson, received the guests and visitors.

The committee has arranged an interesting series of lectures, exhibits, demonstrations and visits, which, together with the lighter entertainment and outdoor activities, promise to be well supported.

Apart from any educational value of the Convention, there is no doubt that the interchange of views between members of the various departments and the personal contacts made will prove of great value in maintaining the smooth working of the Post Office Telecommunications Services.

Book Review

"Fundamentals of Vacuum Tubes." A. V. Eastman, M.S. 438 pp. McGraw-Hill. 24s.

The author is the Assistant Professor of Electrical Engineering at the University of Washington, and has based his book on the requirements of the senior electrical engineering students in this subject. He has confined the subject matter to the theory underlying the operation of all kinds of vacuum tubes, both radio and industrial. Brief descriptions of the construction of the valves are given, the fundamental equations deduced and the applications in typical circuits explained.

Throughout the book the use of mathematics is restricted. Nowhere is a knowledge beyond simple calculus assumed, and most of the mathematical analyses are supported with descriptive matter, so that anyone familiar with the fundamentals of alternating current theory should have no difficulty in following them.

The ground covered is extensive. In the introductory chapters the principles of two to five-element valves, mercury arc rectifiers and photo-electric cells are discussed, electronic emission and the governing laws explained and the symbols and notations listed. The following chapters deal with diodes, including tungar rectifiers, phanotrons, cold cathode rectifiers and mercury-arc rectifiers; class A amplification with triodes; relay action; theory and use of the thyraton and ignitron; class B and C amplification; triode oscillators and inverters; triodes as modulators and demodulators; multi-element valves; photo-sensitive cells and special vacuum tubes such as X-ray and cathode ray tubes, etc. The book concludes with two appendixes dealing with the Fourier analysis of repeating functions and a subject and author index.

It will be seen that the ground covered is immense, and in a book of 438 pages it is impossible to deal with the subject exhaustively. The author has, however, succeeded in giving the reader a very sound survey of the types, theory and uses of vacuum tubes. Although written by an American there is little which is not equally applicable and useful to the British student or engineer.

The author can perhaps be criticised for devoting some 350 pages to the triode and only 25 to multi-electrode tubes and 4 to the cathode ray tube, but he is concerned more with basic principles than modern applications.

This book should be read by all electrical engineering students.

H. L.

The Institution of Post Office Electrical Engineers

ESSAY COMPETITION, 1936-37.

The Judges have reported to the Council that the Prize Winners in the recent Essay Competition, arranged in order of merit, are as follows :—

A. P. Fleming, London. " An Examination of Psychology and its Applications to Industry."

M. C. Long, Torquay. " Specialisation within the Department with Specific Reference to the Training of Youths."

W. R. Thistlewaite, Kendal. " Television."

C. F. Bougourd, Ryde. " Supervising Contractors on Exchange Construction."

T. F. Mackay, Birmingham Test. " Photography and Engineering."

The Council has decided to award Certificates of Merit to the following five competitors who were next in order of merit :—

C. E. Woolley, Derby. " Main Cable Testing. An Outline of Methods and Procedure."

H. W. F. Edwards, Dollis Hill. " The Development of Ultra Short Wave Radio-Telephone Circuits by the Post Office in the British Isles."

S. G. Miller, Bristol. " Radio Communication. Short Wave Propagation, Aerials and Transmission Lines."

A. Jones, Manchester. " The Working of Central Normal Stock and Replacement Depot Scheme."

W. J. Seath, Edinburgh. " Local Line Development Schemes."

There were 43 entries and the Judges reported that the standard of merit of the essays is sufficiently high to merit the award of the full number of prizes and certificates.

RETIRED MEMBERS.

The following corporate members, who have retired from the Service, have elected to retain their membership of the Institution :—

W. G. Morris, " Sandown," Priory Lane, Penwortham, Preston.

J. F. Fletcher, M.I.E.E., 158 Stretford Road, Ormston, Liverpool.

W. Wood, 72 Cambridge Road, Liverpool, 21.

CORRESPONDING MEMBERS.

The following have been elected :—

A. J. McDevitt, Engineering Branch, P.M.G.'s Dept., 219 Castlereagh Street, Sydney, New South Wales.

E. H. Davies, Engineering Branch, P.O. Goulburn, New South Wales.

Junior Section Notes

Leeds Centre

A very successful session for 1936-7 has to be reported. The programme arranged was as follows :—

October, 1936—" Any Questions."

November, 1936—" House Exchange System." Mr. J. W. Ferguson.

December, 1936—" ' ENG ' Service." Mr. R. W. Burden.

January, 1937—" Petrol from Coal." Mr. E. M. Thomas.

February, 1937—" Alternating Current—Workshop Application." Mr. T. Rowson.

March, 1937—" The 2000 type Selector." Mr. T. C. R. Harrison.

April, 1937—" Film Display." Mr. T. C. R. Harrison.

It is pleasing to report that all the papers were read by members of the Centre and well received.

The prize presented by Mr. H. McLean, Assistant Engineer, Leeds Area, for the best paper read and judged by Mr. A. E. Morgan, Regional Engineer, was awarded to Mr. J. W. Ferguson, Youth-in-Training, Leeds, for his paper on " House Exchange Systems."

The Centre desire to thank the President, G. P. Milton, Esq., for his valuable assistance during the session, and also Messrs. The Automatic Electric Co., Ltd., for the loan of apparatus, etc.

A visit was paid to the " Yorkshire Evening Post " headquarters during the session which well rewarded those who attended.

The attendance at meetings has been well up to the average ; Wakefield members have particularly shown a keen interest and the Committee are anxious that the session 1937-8 shall be an even greater success.

At the Annual General Meeting the following officers were elected for 1937-8 :—

Chairman—Mr. H. McLean.
Vice-Chairman—Mr. C. H. Booker.
Secretary and Treasurer—Mr. T. C. R. Harrison.
Committee—Messrs. H. Atkinson, J. Field, E. J. Parsons, J. W. Ferguson.

The Chairman has again offered a prize for the best paper presented during the 1937-8 session and the Committee trust that a good response to their appeal for papers from the members will result.

The Committee feel that the opportunities offered through membership of the Junior Section by the use of the library, etc., are such that warrant the very close interest of all the staff. Enquiries by all interested are cordially invited by the Committee.

Manchester Centre

The 1936-7 session of the Manchester Centre of the Junior Section has proved, as its forerunners, to be most successful. During the session, an increase of membership of over 100 per cent. to its present figure of 215, was achieved.

A total of 12 meetings and 9 visits were arranged, and whilst the attendance generally was rather disappointing, it is anticipated that this will be remedied at the commencement of the next session.

The election of officers for the ensuing session resulted as follows :—

Chairman—Mr. J. Pratt.
Vice-Chairman—Mr. A. Jones
Hon. Secretary—Mr. R. S. I. Ogden.
Hon. Asst. Secretary—Mr. A. R. Powell.
Hon. Treasurer—Mr. R. R. Gaythorpe.
Librarian—Mr. A. Whiteley.
Committee—Messrs. Dearden, Potts, McGosh, Cowen, Wilson and Albert Jones.

Subscriptions are now due and should be paid to the Hon. Treasurer or to any officer or member of the Committee.

The Committee will shortly be commencing the compilation of the session's programme, and would welcome any suggestions or offers of papers from members.

Local Centre Notes

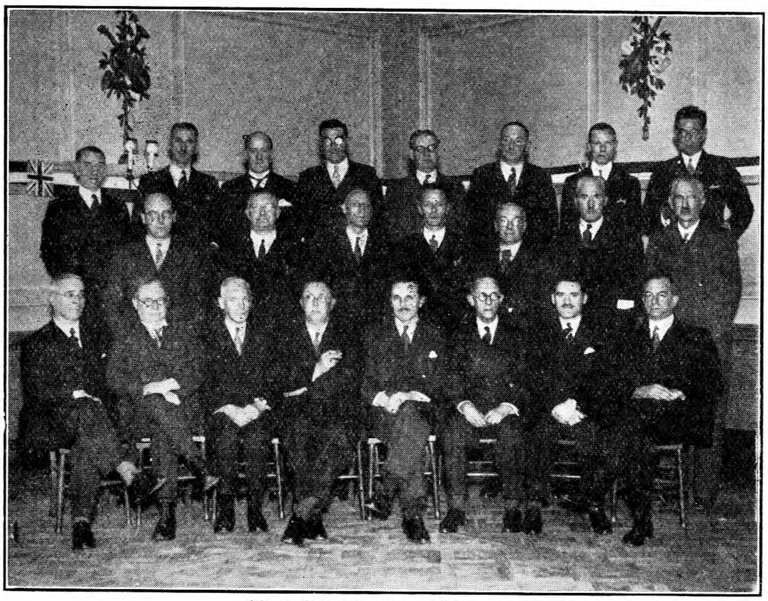
North Wales

VISIT OF I.P.O.E.E. COUNCIL TO SHREWSBURY

So rarely does the Council of the I.P.O.E.E. meet outside London that a visit to the Provinces must be regarded as a privileged occasion and when, after the lapse of seventeen years, the invitation of the North Wales Centre to meet in Shrewsbury was accepted by the governing body no effort was spared to make the event memorable in the history of the Centre.

The visit took place on 18th and 19th March, 1937, and a comprehensive programme of District activities and social entertainment was arranged by a sub-committee under the chairmanship of Mr. H. G. S. Peck (Vice-Chairman of the Centre and District A.S.E.). So fully occupied was the time available that it was necessary to time the programme to minutes, and it says much for the capable organisation of the committee that the schedule was adhered to without hitch throughout the stay.

The members of the Council converged on Shrewsbury at midday on 18th March and were met at the Station by Messrs. H. Faulkner (S.E.), Watkins and Peck (A.S.E's). After lunch, the party, now reinforced by over 200 members of the Centre and other visitors, including the Head Postmaster of Shrewsbury and the District Managers, Birmingham and Chester, together with members of their staffs, met to hear a Paper on "The Rectification of Alternating Current by Static Rectifiers," by Mr. L. J. Dore of the Birmingham Technical Staff, in the ballroom at Morriss's Café. The room was already in Coronation dress, thus adding to the festive occasion. The discussion following the reading of the Paper was ably led by Col. A. S. Angwin. A number of other visitors took part and curtailment of the proceedings was necessary at 5.30 p.m.



THE INSTITUTION COUNCIL.

Following tea, conducted tours were arranged among the many interesting and historic amenities of the town.

At 7.0 p.m. the Members of the Council were entertained at a complimentary Supper in the famous Elizabethan Rooms at Morriss's Café; Mr. Faulkner presiding over an attendance of 200 guests. After the Loyal Toast had been honoured the Chairman proposed the toast of "The Institution of Post Office Electrical Engineers." After voicing the warm welcome of all the members of the North Wales Centre to their guests who were visiting the greatest Provincial stronghold of the Institution, the Chairman referred to the excellent work which is performed by the Senior and Junior bodies, to the world-wide interest in its activities which is maintained through the medium of the P.O.E.E. Journal, and stressed the fact that the functions of the Institution enabled every member, irrespective of rank, to meet on a common level in the consideration of the problems peculiar to the telecommunication engineer. Coupling with the toast the name of the Chairman of the Council, Mr. Faulkner paid tribute to the ability, wise guidance and humane inspiration which were exemplified in Colonel Angwin's administration, and followed with many happy memories and anecdotes of his long association with the Deputy Engineer-in-Chief both at home and abroad, and at various Conferences at which they had represented the British Post Office. Colonel Angwin replied in a witty speech similarly reminiscent. On behalf of the Council he expressed appreciation of the handsome manner in which they had been welcomed and entertained; their visit had, indeed, enabled them to "show the flag" in a unique manner and over a very wide area.

An excellent programme of Magic, Mirth and Melody followed, most of the Artistes being members of the District Staff, including Messrs. E. Bate, P. R. T. Clarke, F. W. Hart, T. J. Jones, R. Newton, S. Woods, E. J. Haycock and R. Lindsay. Much interest (and laughter) was displayed in a unique demonstration of Cable Balancing as practised, unofficially, in the District by the ever-popular Freddie Hart, of the Headquarters Drawing Office Staff. The Cable was a three-foot length of P.C.Q.L., the fulcrum being "Freddie's" nose and chin! A lively entertainment continued until 11.30 p.m., when the guests dispersed to headquarters as far apart as Bangor and Birmingham.

The Council met for its private deliberations on the morning of 19th March and after lunch proceeded to Birmingham for a tour of the newly opened Telephone House.

In addition to the social side, which was unanimously voted to be an outstanding success, the opportunity for the exchange of ideas and consultation with Grade representatives contributed largely to make the visit a memorable occasion.

S. T. S.

District Notes

South Lancs.

LIVERPOOL AUTO, DUCT WORK SCHEMES.

In connection with the change over to automatic working, and the transfer of three exchanges and the repeater equipment to new premises at "Lancaster House," the extensive underground network has to be rearranged and underground contract works to the value of approximately £52,000 are at present in progress and further schemes have still to be carried out. The works in hand involve the laying of the following lengths.

Classes of Conduit	
10 yards	128-way octagonal duct
73 yards	99-way octagonal duct
457 yards	63-way octagonal duct
134 yards	36-way octagonal duct
412 yards	35-way octagonal duct
37 yards	32-way octagonal duct
36 yards	28-way octagonal duct
907 yards	24-way octagonal duct
1,640 yards	20-way octagonal duct
104 yards	16-way S.A. duct
133 yards	15-way S.A. duct
430 yards	12-way S.A. duct

and various other types of single and multiple way duct.

At Lancaster House three leads-in are being provided, a 128-way and 33-way from the manhole at the south end, and a 32-way from the manhole at the north end of the building, the connection between these manholes being via the cable chamber in the building. The 33-way duct has been provided for the leading-in of repeatered cables and the 128-way for junction and local cables. The 32 way will accommodate all classes of cables from the north side of the city. The manhole at the south side of Lancaster House is seven sided, and the internal dimensions are approximately 13 ft. 5 ins. long by 13 ft. wide by 13 ft. high and the manhole extends more than half-way under the carriageway. Adjacent to this manhole two further manholes have to be constructed to provide for the diversion of the existing cables, and the whole width of the carriageway will be covered by the Department's manholes when the work is completed.

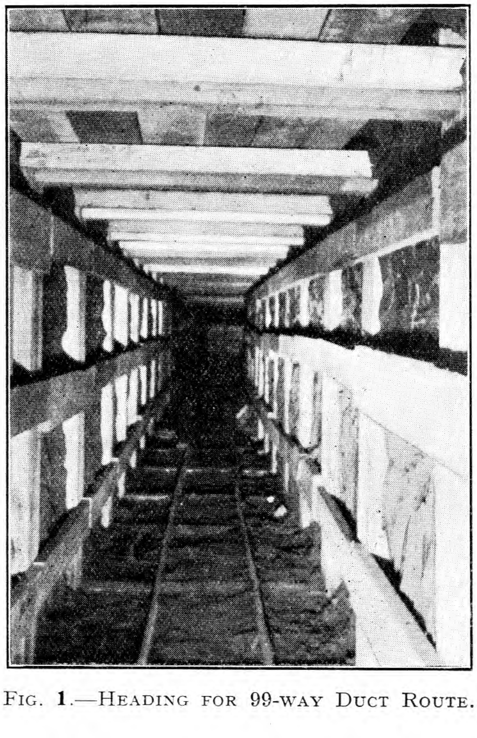


FIG. 1.—HEADING FOR 99-WAY DUCT ROUTE.

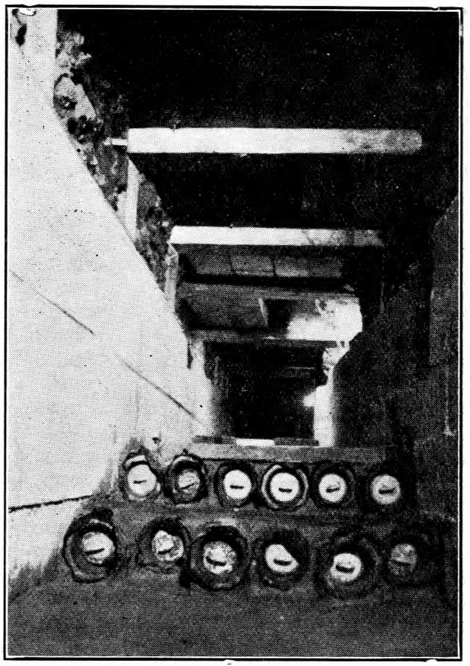


FIG. 2.—BOTTOM LAYERS OF 36-WAY DUCT ROUTE.

The depth of the exchange manholes from the road surface is 18 ft. 1 in., which has been necessary on account of the obstructions by sewers, drain connections, and to provide for a fall in the duct line from the exchange basement. A 99-way Octagonal duct (Fig. **1**) is in the process of being laid from this manhole in a southerly direction, and on account of the exchange manhole being below the existing sewer levels, arrangements have been made to lay a 4 in. S.A.D. to carry the surface water from the manhole underneath the 99-way and a section of the 36-way octagonal ducts (Fig. **2**) via three manholes, until it is possible to connect to a sewer at a lower level of the City, which has a different point of discharge. This will ensure that the three manholes will be free from water at all times.

In the last manhole a Couzens trap with both gas and water seal has been fitted to prevent sewer water or gas entering the manhole. The depth from the surface to the base of the large nest of ducts varies from 17 ft. 2 ins. to 25 ft. 6 ins. to provide a fall of 1 in. in 36 ins. for draining the exchange manhole and to provide for side shafts for footway entrances to the manhole, which pass below the sewer. Approximately half of the work has been executed in tunnel due to traffic conditions, and also due to the fact that it was less costly to execute the work in tunnel than by open cut method on account of the depth at which it has been found necessary to lay the duct. No abnormal obstructions have been encountered, and the worst difficulties have consisted of meeting foul water and sewer connections at various levels of which there were no local records. In a trench at a depth of 9 ft. the Contractor was engaged in pumping for four days with a motor pump, but the amount of water was not reduced until the fifth day, when it was found that the water was entering the trench via some arched basements of old property approximately 3 feet below the existing pavement. These basements were adjacent to tenement buildings which were erected on the site of an old tannery, and it is thought that the old basements were part of a cesspool. A chemical analysis of the foul water revealed that the constituents were injurious to portland cement concrete and lead, and arrangements were therefore made with the local Authority for a connection to be made to the sewer at this point and 6 in. agricultural drain surrounded by hardcore laid at a depth of two feet below the foundation of the octagonal duct to ensure that any seepage of foul liquid from the ground is taken direct into the sewer. Aluminous cement was used in lieu of portland cement for the octagonal duct surround for a distance of 20 yards on either side of the point where the liquid was encountered, as this class of cement is more resistant than portland cement to practically every known chemical substance which attacks concrete.

The standard method of laying the octagonal duct has not been carried out, as from previous experience it was found that the work could be more efficiently executed by the Contractor, and the likelihood of any defect in the concrete surround is reduced to a minimum, when the base and walls to the duct are constructed in advance of ductlaying operations. The various Contractors agreed to execute the work on these lines.

LAYING AND CLEATING CABLES IN A DIFFICULT SITUATION.

The Runcorn Viaduct forms part of the L.M.S. Railway main line between Liverpool and London, and carries railway traffic over the River Mersey and the Manchester Ship Canal. The elevating approaches to the Viaduct pass through the towns of Widnes and Runcorn, situated on the north and south banks of the Mersey respectively. The approaches are constructed of embankments and arched masonry and are contiguous with the over-river portion of the Viaduct which consists of horizontal spans of steelwork supported on stone piers placed in the river bed. The Viaduct and a transporter bridge which operates between Widnes and Runcorn are the only available means, apart from subaqueous, by which the direct routing of telephone cables between the river banks can be effected. The adoption of subaqueous cable is considered uneconomical in the circumstances involved.

Some years ago lead-covered cables were laid on the transporter bridge, but the vibration set up in the bridge structure by the travelling car so affected the cable sheaths that faults were comparatively frequent, and this routing was abandoned.

In 1922 two cables were laid on the Viaduct. The work was carried out by contract and special precautions taken to minimise the effect of vibration on the cable sheaths. The precautions taken have proved successful, no faults having developed since the cables were installed. The method adopted was to provide a wooden trough of creosoted timber sufficiently wide to accommodate the two cables and leave a surrounding space of approximately two inches. This space was filled with a special viscuous compound which, acting as a shock absorber, impedes the transmission of vibration to the cables. The trough is designed to accommodate two layers of cables, and the object of this article is to describe briefly the method and organisation adopted in laying the third cable between Widnes and Runcorn.

FIG. **1**.—RUNCORN VIADUCT.

For Departmental reasons it had been decided to restrict the length of cable running parallel with the railway metals to a section of less than 440 yards. This procedure involved the cleating of the cables to two piers giving a downward lead to—(*a*) the south bank of the river where the cables are led from the piers to a manhole via wooden staging and steel pipes. (*b*) to the foreshore on the north side of the river where the cables enter a concrete chase and are led via a 4-way S.A. multiple duct laid in the foreshore to a manhole situated on the river bank. Cleats to accommodate four cables had already been fixed to the piers.

The third cable is a 74/40 P.C.Q.T. Ordinary cable was laid in the compound on the Viaduct and light armoured type used on the piers and under the foreshore.

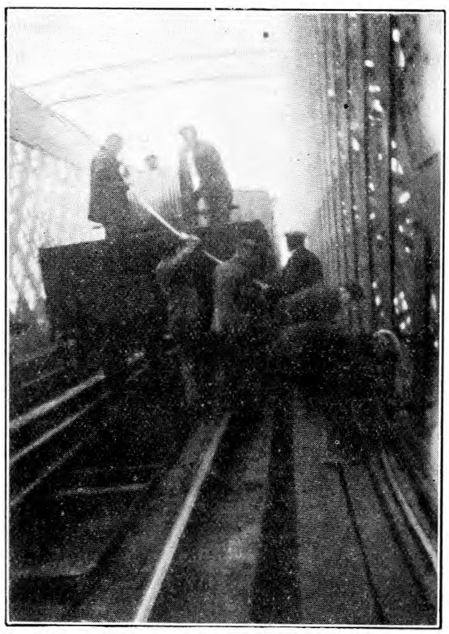


FIG. **2**.—CABLE LAYING OPERATIONS.

The Viaduct carries two sets of metals. The cable trough is laid on the west side adjacent to the " down " line, where accommodation for a working party is extremely limited. The normal train service, passenger and goods, is very frequent, trains passing on the down line at approximately ten-minute intervals. When a train is passing the working party must seek safety in manholes or among the steel lattice of the viaduct.

It was obvious that the operations involved in the laying of the cable could not be carried out without the co-operation and service of the railway company, and arrangements were made to discuss the matter with the district engineer and traffic superintendent on the site.

It was decided to carry out work on Sunday. The railway company agreed to close the " down " line to traffic and provide an engine and brake with two wagons.

The cable drum was mounted, tools and stores loaded, and the covers removed from the cable trough on the previous Saturday.

The wagon conveying the cable drum was in the required position at 7.20 a.m. on Sunday. Seventy-five yards of cable were drawn off the drum and passed under various obstructions (Fig. **1**). The wagon was then propelled " dead slow " and the drum revolved as the wagon proceeded. (Fig. **2**.) Three men controlled the drum as the remainder of the gang arranged the cable in the trough. These operations were completed by 8.10 a.m. The 8 tons of compound were then discharged to two dumps of 4 tons each at either end of the Viaduct, and the engine and wagons released.

The operations involved in cleating the armoured cable to the pier at the Runcorn side of the river did not present much difficulty. (Fig. **3**.) The length of cable on the pier is approximately 100 ft. By means of a jib fitted on the permanent way above it was possible to facilitate the work by dropping a rope from a block attached to the jib through the appropriate cleats nearly all the way down the pier and draw the cables up by means of block and tackle fixed at the lower end. Suitable accommodation for a winch was not available at this point.

The cable was secured to each cleat by split hollow cones made from hardwood, and pickled. The cones were lined with sheet lead and a mild steel clamp securely bolted to the cable fitted above, and sitting on the hardwood cone at each point. The centripetal force applied will, therefore, insure stability.

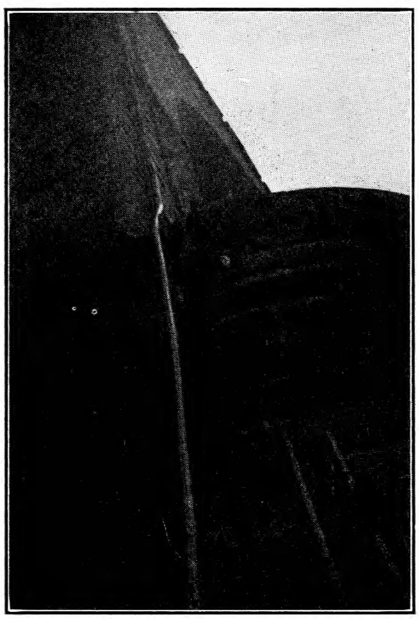


Fig. **3**.—Cleating to the Pier.

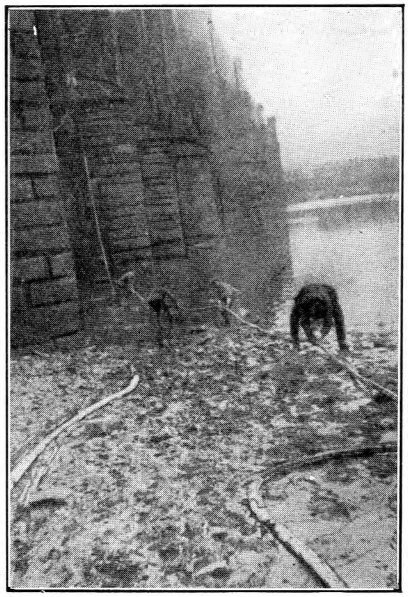


Fig. **4**.—Paying Out the Widnes Shore End.

Operations on the Widnes side were more involved. The lower end of the pier to which the cables are attached is generally submerged and the tide table had to be consulted in order to determine a suitable period which would allow the maximum amount of time to carry out the necessary operations.

At the foot of the pier the 4-way duct leading from the manhole on the river bank terminates in a small concrete box fitted with a detachable lid. Jointing at this point was obviously impossible, and it was considered desirable to avoid a joint in the armoured cable if possible. The small capacity of the concrete chase precluded the possibility of making a straight draw from the manhole, and up the pier. Snatching through the concrete chase would have been a waste of time, and the turn of the tide had to be considered. It was decided to undrum the cable on the shore (Fig. **4**), and send the anti-clockwise end up the pier in a manner similar to that adopted on the Runcorn side. A rope was then passed down the 4-way duct from the manhole and the cable drawn in. Great care was necessary in order to avoid a twist or kink in the cable, particularly on the last draw, when the bight entered the concrete chase.

There are only two joints between the manholes on the north and south sides of the river, approximately 600 yards, and both are easy of access.

Eastern

RECOVERY OF OVERHEAD MAIN LINE FROM GRAND JUNCTION CANAL

This line was the principal of three overhead lines connecting London with Fenny Stratford and beyond towards the North.

The main circuits were diverted to existing main cables during 1936. To permit of the clearance of local circuits, new main underground duct lines with loaded and balanced cables were provided between Leighton Buzzard and Fenny Stratford and between Newport Pagnell and Stony Stratford, while additional leading-in points to existing main cables were made at Apsley Mills, Berkhamsted and Tring. A number of overhead rearrangements were also executed.

The total mileage of wire recovered was approximately 3,200 miles and the scrap value realised for wire alone was £11,630. The poles had no recovery value, and by special arrangement 1,176 were handed over to the Canal Company in situ.

The balance of 84 H and A poles and 240 single poles were not accepted by the Company and recoveries of these poles with approximately 27,200 arms are nearly completed.

Canal boats were used for collection and conveyance of wire and other recovered stores, and arrangements were made with the Controller, Stores Department, for the direct collection of the scrap wire by the purchasers.

South Wales

STORM DAMAGE

Considerable damage was caused to the Department's overhead plant by a blizzard which swept South Wales during the night of the 27th and 28th February. In the Swansea section alone well over 2,000 subscribers' lines were affected and about 80 exchanges isolated. After an extremely wet month the country was waterlogged and heavy trunk and subscribers' routes had little chance to withstand the violence of the wind coupled with the weight of snow on the wires. Repairs were placed in hand with the usual celerity and services were quickly restored.

Scottish Region

RETIREMENT OF MR. W. J. EVES, A.M.I.E.E.

Mr. W. J. Eves, A.M.I.E.E., Area Engineer, Aberdeen, retired on the 30th of April last, after 45 years' service in the Post Office. In common with many other engineers, Mr. Eves began his career on the telegraph side and saw service in Bridport (1892) and Bristol (1897). He was transferred to the Engineering Department in 1903, with Headquarters at Cardiff.

In 1907 Mr. Eves was appointed Sub-Engineer at Birmingham, was promoted to Sectional Engineer in 1932 and was transferred to Aberdeen. On the setting up of Regionalisation in Scotland in 1936 Mr. Eves became Area Engineer, this new Area embracing the greater part of the old Aberdeen Section and the whole of the former Inverness Section. (The staff controlled had reached 550 prior to Mr. Eves' retirement.)

Mr. Eves, who was awarded the Jubilee Medal in 1935, took a keen interest in technical education and was for many years a teacher in "City & Guilds" subjects. He was a bronze medallist in Honours Telegraphy and it is interesting to note that five of his students also gained medals. A man of wide knowledge and experience, and of kindly and helpful disposition, he quickly found his way into the affection and esteem of his staff, whose efficiency and well-being were always his anxious care.

A company of over 200 colleagues and friends assembled in the Bon-Accord Hotel, Aberdeen, on the evening of his retirement to do him honour and bid him an official farewell.

The Chair was occupied by Mr. J. G. Ferguson, Telephone Manager, Aberdeen, who introduced the various speakers, amongst whom may be mentioned Mr. B. O. Anson, A.M.I.E.E., Assistant Engineer-in-Chief; Mr. C. A. Taylor, M.C., Deputy Regional Director, Edinburgh; Mr. J. J. McKichan, O.B.E., M.I.E.E., Chief Regional Engineer, Edinburgh; Capt. Cave-Brown-Cave, Superintending Engineer, Cambridge; Mr. W. V. Ryder, M.I.E.E., Assistant Superintending Engineer, Edinburgh; Mr. D. H. Davies, Head Postmaster, Aberdeen, and Mr. J. Ramsay, Principal Clerk, London.

The presentation of a cabinet and work table to Mr. and Mrs. Eves on behalf of the staff and friends was made by Mr. McKichan, who warmly complimented Mr. Eves on his work, and wished the recipients health and happiness in their retirement.

Mr. Eves has a number of interests outside his official duties, photography, microscope work, gardening, etc., which he will now be able to follow without restraint. We are glad to know he is active, hale and hearty, and well able to enjoy his leisure pleasantly and profitably. May he long continue so to do.

AYR AGRICULTURAL SHOW—28/29 APRIL.

This was a particularly successful event from a Post Office point of view. The mobile Post Office was used for the first time in Scotland, and two Call Offices and a Teleprinter were in operation.

The Duke and Duchess of Gloucester attended the show, and were received at the Post Office by Lt.-Col. F. N. Westbury, C.B., O.B.E., Regional Director for Scotland.

FIRE EMERGENCY, KIRKWALL EXCHANGE.

The switchboard was severely damaged by fire on May 15th and all communication stopped. Restoration of the service was effected with commendable promptitude and the measures adopted were notable in that this is

probably the first time that aeroplanes were used for the purpose of conveying men and a temporary switchboard to the scene. Service was given to 80 subscribers on the same day and the remaining 80 were working satisfactorily by the 17th instant.

North Wales

BIRMINGHAM AREA REORGANISATION

By the end of last year the number of workmen in the Birmingham Section, having reached 1,300, was still growing and was to be expanded further by the transfer of parts of the Gloucester, Hereford, Shrewsbury and Stoke Sections. A revision of the engineering organisation and an increase in the supervising force therefore became a matter of urgency.

After preliminary discussions with the Engineer-in-Chief there were discussions with the Superintending Engineer, South Lancashire District, who was concerned with a similar problem at Manchester, and a joint scheme was eventually evolved on lines which would fall in with the requirements under Telephone Area conditions.

It was decided that a functional organisation should be retained and that it should apply the same principles of Planning and Control to the group of Executive Engineers as had been instituted for certain section staffs. Up to this time the organisation consisted of three functional sections, viz. External, Internal and Power, and the revised grouping which was introduced on March 20th last was as follows :—

(1) Planning and Control, (2) Maintenance, (3) Works, (4) Installation.

The Control Engineer has an allowance in order to enable him to function as a liaison officer as far as the other three sections are concerned. He is responsible for all matters preliminary to the actual allocation and execution of the work. Thus he is responsible for all development schemes and annual estimates, preparation of specifications, accommodation, etc. He is also responsible for planning ahead and endeavouring to foresee staff requirements and advise the other Engineers as to the staff which should be recruited and trained to meet future requirements. He is responsible also for staff movements as between the sections which may be necessary owing to changes in the incidence of the work.

The Sectional Engineer in charge of maintenance is responsible for all maintenance work in the section whether internal or external, underground or overhead, and power. He is responsible for all inspections, renewals, precision testing for faults, electrolysis cases, radio interference, in fact for everything which appertains to the maintenance of plant in the section. This arrangement, it is considered, is an improvement on the old arrangement whereby the Internal section had of necessity to call on the External section for assistance whenever external plant was concerned. It also overcomes the troubles due to divided responsibility which formerly existed from this reason. It will still be necessary on occasion to call on the Works section, but by the use of the reserves which the Maintenance section possesses in the way of line inspection officers, men engaged on renewals, etc. this necessity will be reduced to a minimum. In case of necessity, however, the liaison functions of the Control Engineer can be called upon and he will determine from which other section the necessary staff should be drawn.

All works other than Advice Notes and Minor Works are the responsibility of the Sectional Engineer in charge of the Works section. This again has advantages from the organisation point of view. For example, at an exchange transfer one engineer is responsible for all the work, both internal and external, and the co-ordination of these works is in his own hands. Thus one of the principal objections to the functional organisation previously in vogue is eliminated.

The fourth section is concerned with all Installation work, whether subscribers' apparatus or P.B.X. The Area is divided into several Advice Note Controls and in order to smooth out the flow of the work, minor works up to 100 man-hours, i.e. such as can be dealt with under the new estimating procedure, are also carried out by this section. This ensures that most of the work is of the same character and can be catered for by the one Advice Note Control organisation.

The re-organisation, thanks to the whole-hearted co-operation of the engineers and staff concerned, was carried out smoothly and it is hoped that considerable improvements will result from its inauguration.

South Midland

A MOBILE TELEPRINTER SCHEME FOR SOUTHAMPTON DOCKS.

An interesting experiment in Teleprinter working has been successfully concluded at Southampton resulting in a considerable speeding up of telegraph traffic received from liner passengers using the port.

Prior to the experiment, telegrams were handed in at special kiosks, conveyed from there by messenger to the Instrument Room, and disposed of by the normal telegraph channels. In anticipation of an abnormal influx of visitors for the Coronation festivities, the Head Postmaster, Mr. A. T. Bell, desired to speed up the telegraph arrangements, and to that end, originated a scheme entailing the use of a Mobile Post Office equipped with a teleprinter, that could be taken to any dock shed, and transmit telegrams direct from the dock side to the Central Telegraph Office.

The docks area extends over a distance of several miles, and it will be appreciated that if time was to be saved, the cutting out of all pedestrian and cycle traffic by messengers was highly desirable.

Unfortunately it was not possible to obtain the body required for the mobile van prior to the Coronation traffic. Mr. Bell then suggested that a teleprinter unit that could be transported readily, and used at the various handing in kiosks, would meet the requirements.

It should perhaps be stated that the normal telephone traffic in the docks area is controlled by the Southern Railway P.B.X., and the use of P.O. telephones to facilitate arrangements for handling heavy consignments of mails was also desired to be incorporated in the telegraph scheme

Such was the problem to be faced, and the solution of it is thought worthy of interest.

A mobile teleprinter unit was designed consisting of a Teleprinter 3A, Converter Rotary No. 3, Unit Auxiliary Apparatus TG.1020, and associated apparatus wired up to Diag. T.G. 1035B. The whole was mounted on a Stand Testing No. 9, making a compact mobile unit. Power was already available at each kiosk, and the usual teleprinter plug connections were provided. A teleprinter line jack was also fitted and joined to a flexible lead terminating on a Plug No. 201 Red, to afford a means of connection to the line network.

In co-operation with the Southern Railway Company, lines were run from the most important berths (i.e. those handling the North American and South African traffic) to the Instrument Room, which is at the dock gates. This involved circuits to eight different berths where the lines were led out to special boxes fixed to stanchions in the dock sheds, and there connected via a protector and break jack to a Telephone 162 S. The boxes are kept locked, and only authorised postal officials holding keys have access to them.

At the Instrument Room a cordless switchboard of the $\frac{3 \times 9}{12}$ type was fitted, and above it a strip of ten break-jacks. The lines from the berths were connected via eight of the break-jacks to extension positions on the board. Two lines from the Voice Frequency Telegraph Control board were terminated on the other two break-jacks. Thus, by means of double-ended cords, any extension can be put through to the V.F. control board, and the P.B.X. cut out of circuit. Two normal exchange outlets were also provided.

The scheme of operation is as follows :—

When a liner berths, the telegraph officer on duty unlocks the box, and lifts the telephone receiver, thereby calling the P.B.X., which, being mounted at the end of the phonogram suite, is answered by the nearest operator.

If traffic warrants the use of a circuit to London, a request for connection to the C.T.O. is made. At the berth end, the plug 201 Red is inserted in the break-jack, thereby disconnecting the telephone. At the Instrument Room the calling extension is connected via the double-ended cord and break-jacks to the V.F.

control board, and thence extended over a voice frequency channel to the C.T.O. Thus, a pure telegraph circuit is established, and direct teleprinter working from the dock side can proceed.

Two portable telephones have also been supplied and, should a vessel berth in another dock while the unit is in use, communication can be established (to the Instrument Room switchboard) as previously described, the portable telephone used in the kiosk instead of the teleprinter, and phonogram facilities are obtained. Further, should a postal superintendent wish to make special arrangements for transport of mails, the telephone housed in the box can be used via the exchange lines to any place desired, full exchange facilities being available.

On the completion of traffic to C.T.O., a request is passed to "Clear Down." The C.T.O. advise the Southampton Instrument Room, and the whole system is restored to normal telephone working.

It is realised that full supervision on the teleprinter circuit is not given, but as the circuits are not in continuous use, and the difficulties to be met in installing and maintaining a Mobile V.F. Teleprinter System over rough roads in Dockland are considerable, the supervision was not considered essential.

It is perhaps of interest to note that between the afternoon of April 21st, when the scheme was first tested, and midnight on May 10th (the peak of the Coronation Traffic), 867 telegrams were transmitted over the system, a proof of the adequacy of the arrangements made.

In conclusion, it should be added that the close co-operation readily afforded by the Southern Railway Company and the Shipping Companies concerned, was of the greatest assistance in bringing the experiment to its successful conclusion.

London

THE CORONATION

As can readily be imagined the Coronation made large calls upon the London District in the provision of special circuits for all the various Government Departments and authorities concerned in the arrangements for this very important event.

The greater part of the work was carried out by the Area and Installation staff of the Central External Section, who also maintained the circuits until their recovery after May 12th. Full details of the circuits and equipment provided are given in an article appearing in this issue.

Mention should be made of the work carried out by the Test Room staffs in running jumpers for the large number of through circuits and exchange lines and the large amount of work carried out at the hotels in the West-end to meet the rush of visitors. It is also interesting to note that the majority of the circuits were routed on alternative routes in case of breakdown of any particular portion.

All the broadcasting, telephonic and telegraphic arrangements worked without a hitch on the day, and great credit is due to the members of the staff, especially those in the Centre External Section, whose careful and thorough work enabled all telephone arrangements to work so satisfactorily.

Technical Publications of the International Tin Research and Development Council

Several technical publications have been received from the International Tin Research and Development Council. Only two are, however, of any direct interest to Journal readers. They are—"Influence of surface cuprous oxide inclusions on the porosity of hot-tinned coatings on copper," and "The hot-tinning of copper: the attack on the basis metal and its effects."

In the former Dr. W. D. Jones shows that one of the main causes of irregular and porous hot-tinned coatings on copper is the presence of cuprous oxide inclusions on the copper surface. Cuprous oxide of course is present in all copper (excepting the special oxygen-free variety), and apparently cannot be tinned. On account of this, microscopic pinholes in the tin coating are produced.

This trouble can be overcome by the use, prior to the hot-tinning process, of one of two treatments to be applied to the copper surface. The action of both is to reduce the cuprous oxide inclusions to copper, thus permitting a non-porous coating to be formed.

In the other publication Mr. E. J. Daniels gives experimental evidence of the presence of two distinct compounds of copper and tin occurring in layers between the basis copper and the tin coating, when the former metal is hot-tinned. These layers tend to detach in fragments as soon as they are formed and to contaminate the tin bath and tin coating. It has been found that, whereas the presence of copper up to about 1 per cent. in the tin coating is conducive to the production of coatings of even thickness, any excess of this figure gives rough coatings.

In practice to obtain the ideal copper percentage in the tin coating careful attention has to be given to the temperature of tinning and to the copper addition usually made to the tin bath.

The conclusions of these two publications are of considerable value to the manufacturers of hot-tinned products, and readers will no doubt realise the importance of this work in connection with the manufacture of hot-tinned copper wire.

Copies of these two publications are obtainable free of charge from The International Tin Research and Development Council, Manfield House, 378 Strand, W.C.2.

E.V.W.

Staff Changes

PROMOTIONS.

Name	From	To	Date
Starkey, N. Y.	Exec. Engr , Eastern	Actg. A.S.E., S. Lancs.	9-4-37
Wallcroft, F. E.	Exec. Engr., E.-in-C.O.	Actg A.S.E., E.-in-C.O.	1-4-37
Reading, J.	Exec. Engr., E.-in-C.O.	Actg A.S.E., E.-in-C O.	9-4-37
Phillips, C. H.	Exec Engr , London	Actg. A.S.E., London	1-7-37
Smith, W. F.	Area Engr., N.E. Reg.	Reg. Engr., N.E. Reg	1-7-37
Jolley, E. H.	Actg. A.S.E., E.-in-C.O.	A.S.E., E.-in-C.O.	1-7-37
Richardson, T	Area Engr , Scot. Reg.	Area Engr. with Allce., Scot. Reg.	4-4-37
Cook, A. G.	Exec. Engr , N. Western	Exec Engr , with Allce. N. Wales	25-4-37
Graham, C.	Exec. Engr., S. Eastern	Exec. Engr. with Allce., S. Lancs.	21-5-37
Cowburn, W	Exec. Engr., N. Western	Exec. Engr. with Allce., S. Lancs.	23-5-37
Hopps, F.	Asst. Engr , N.E. Reg.	Actg. Exec. Engr., N.E. Reg.	14-5-37
Knowens, A. D. V.	Asst. Engr , Eastern	Actg. Exec. Engr., Eastern	9-4-37
Gifford, H. W.	Actg. Exec. Engr., S Wales	Exec. Engr., S. Wales	25-2-37
Brown, A. H	Actg. Area Engr., Scot. Reg.	Area Engr., Scot. Reg	25-2-37
Drury, R. H.	Asst. Engr., E.-in-C.O	Exec. Engr., E.-in-C.O.	22-4-37
Frost, J.	Asst. Engr., N. Midland	Exec. Engr., S. Midland	1-5-37
Bagley, T.	Asst. Engr., N. Midland	Exec. Engr., S. Midland	22-4-37
Morrell, F. O.	Asst. Engr., E.-in-C.O	Exec. Engr., E.-in-C.O.	22-4-37
McIntosh, J.	Asst. Engr., Scot. Reg	Area Engr., Scot. Reg.	1-5-37
Vernon, R. J.	Asst. Engr., E.-in-C.O.	Exec. Engr., E.-in-C.O.	22-4-37
Mayman, A.C.	Asst. Engr., E.-in-C.O	Exec. Engr., E.-in-C.O.	22-4-37
Booth, C.F.	Asst. Engr., E.-in-C.O	Actg. Exec. Engr., E.-in-C.O.	22-4-37
Bocock, W.	Asst. Engr., London	Actg. Area. Engr., Scot. Reg.	22-4-37
Flowers, T. H.	Asst. Engr., E.-in-C.O.	Actg. Exec. Engr., E.-in-C.O.	22-4-37
Scantlebury, L. F.	Asst. Engr., S. Western	Actg. Exec. Engr., Scot. Reg.	1-5-37
Nibbs, A.	Asst. Engr., S. Midland	Actg. Exec. Engr., E.-in-C.O.	22-4-37
Williams, E. H.	Asst. Engr., N. Wales	Actg. Exec. Engr., N. Wales	18-5-37
Taylor, H. M.	Asst. Engr., Scot. Reg.	Actg. Exec. Engr., N. Western	2-5-37
Gould, E. F. H.	Asst. Engr., E.-in-C.O.	Actg. Exec. Engr., E.-in-C.O.	22-4-37
Guest, F.	Chief Insp., Eastern	Asst. Engr , Eastern	15-3-37
Reed, E. C.	Chief Insp., N.E. Reg.	Asst. Engr., N.E. Reg	15-3-37
Partridge, F. V.	Chief Insp , London	Asst. Engr., London	15-3-37
Birch, S.	Chief Insp., E.-in-C.O	Asst. Engr., N.E. Reg.	26-3-37
Trigilgas, A. S.	Chief Insp., London	Asst. Engr , S. Lancs.	15-4-37
Hayward, A. E.	Chief Insp., S. Western	Asst. Engr., S. Western	15-4-37
Knight, E. W.	Chief Insp., S. Midland	Asst. Engr., S. Midland	22-4-37
Johnson, E. W.	Chief Insp., S. Eastern	Asst Engr , London	9-5-37
Smithers, F. A.	Chief Insp., N.E. Reg.	Asst. Engr., N.E. Reg	15-4-37
Bucknall, F. R. B.	Chief Insp., Scot. Reg.	Asst. Engr., Scot. Reg	15-4-37
Markby, E. J.	Chief Insp., London	Asst Engr , Scot. Reg.	18-4-27
Kenyon, T.	Chief Insp., S. Lancs.	Chief Insp. with Allce , S. Lancs.	21-3-37
Mercer, N.	Chief Insp., S. Lancs.	Chief Insp. with Allce., S. Lancs.	13-3-37
Sudell, N.	Chief Insp., S. Eastern	Chief Insp. with Allce , S. Eastern	11-3-37
Gordon, J. T.	Chief Insp., S. Wales	Chief Insp. with Allce., S. Wales	12-3-37
Halliday, C. W.	Chief Insp., N. Wales	Chief Insp. with Allce., N. Wales	20-3-37
Johnson, R. P.	Chief Insp , N. Wales	Chief Insp. with Allce., N. Wales	20-3-37
Willmott, C. J.	Chief Insp , S. Midland	Chief Insp. with Allce., S. Midland	13-3-37
Attenborough, F. C	Chief Insp., N. Wales	Chief Insp. with Allce., N. Wales	20-3-37
Mealing, W. P.	Chief Insp , N.E. Reg	Chief Insp with Allce., N.E. Reg.	21-3-37
Morvan, A. R	Chief Insp., N Wales	Chief Insp. with Allce., N. Wales	20-3-37
Smith, B. J.	Chief Insp., S. Western	Chief Insp. with Allce., S. Western	14-3-37
Padget, A.	Chief Insp., S. Midland	Chief Insp. with Allce., S. Midland	21-3-37
Harris, R.	Chief Insp , S. Western	Chief Insp. with Allce , S. Western	14-3-37
Hibberd, R. M.	Chief Insp., N. Midland	Chief Insp. with Allce., N. Midland	14-3-37
Stank, W.	Chief Insp., Scot. Reg	Chief Insp with Allce., Scot. Reg.	11-3-37
Scott, F.	Chief Insp., N.E. Reg	Chief Insp. with Allce., N.E. Reg.	28-3-37
Micklejohn, G. F.	Chief Insp., Scot. Reg	Chief Insp with Allce., Scot. Reg.	21-3-37
Hilton, W. B.	Chief Insp., S Lancs.	Chief Insp. with Allce., S. Lancs.	11-3-37
McCann, J. L.	Chief Insp., S. Western	Chief Insp. with Allce., S. Western	14-3-37
Tait, W.	Chief Insp., N. Midland	Chief Insp with Allce., N. Midland	14-3-37
Davidson, T.	Chief Insp., Scot. Reg.	Chief Insp. with Allce., Scot. Reg.	11-3-37
Heaton, A.	Chief Insp., S. Lancs.	Chief Insp. with Allce., S. Lancs.	21-3-37
French, W. S.	Chief Insp., N. Ireland	Chief Insp with Allce., N. Ireland	14-3-37
Sutter, A. S.	Chief Insp., Scot. Reg.	Chief Insp with Allce., Scot. Reg.	28-3-37
Read, A. J.	Chief Insp., N. Midland	Chief Insp. with Allce., N. Midland	14-3-37
Hepplestone, H.	Chief Insp., S. Lancs.	Chief Insp with Allce., S. Lancs.	21-3-37
Baldey, C.	Chief Insp., N. Wales	Chief Insp. with Allce., N. Wales	20-3-37
Ashton, H.	Chief Insp., N. Western	Chief Insp with Allce., N. Western	11-3-37
Edmondson, J.	Chief Insp., N.E. Reg.	Chief Insp. with Allce., N.E. Reg.	21-3-37
Brown, J.	Chief Insp., Scot. Reg	Chief Insp. with Allce., Scot. Reg.	17-3-37
Burrell, G. E.	Chief Insp., N.E. Reg.	Chief Insp. with Allce., N.E. Reg.	26-3-37
Browning, W. H.	Chief Insp., London	Chief Insp with Allce., London Postal Reg.	1-5-37

Name	From	To	Date
Brown, W. J.	Chief Insp., London	Chief Insp. with Allce., London Postal Reg.	1-5-37
Smith, G. W.	Chief Insp., S. Eastern	Chief Insp. with Allce., S. Eastern	15-4-37
Haigh, H. L.	Chief Insp., N.E. Reg.	Chief Insp. with Allce., N.E. Reg.	30-5-37
Burrows, W. N.	Chief Insp., N.E. Reg.	Chief Insp. with Allce., N.E. Reg.	18-4-37
Knott, L. F. H.	Chief Insp., Eastern	Chief Insp. with Allce., Eastern	16-5-37
Tootell, T. E.	Chief Insp., N. Western	Chief Insp. with Allce., N.E. Reg.	6-6-37
Davey, J.	Insp., S. Lancs.	Chief Insp., S. Lancs.	13-3-37
Lockwood, R. A.	Insp., S. Midland	Chief Insp., S. Midland	20-3-37
Cox, C. R.	Insp., S. Lancs.	Chief Insp., S. Lancs.	13-1-37
Devon, H.	Insp., S. Lancs.	Chief Insp., S. Lancs.	17-1-37
Read, P. J.	Insp., S. Western	Chief Insp., S. Western	31-1-37
Pattinson, B. C.	Insp., N. Wales	Chief Insp., N. Wales	26-7-37
Smith, J. A.	Insp., Scot. Reg.	Chief Insp., Scot. Reg.	2-12-36
Price, W. H.	Insp., S. Lancs.	Chief Insp., S. Lancs.	21-3-37
Ridd, J. E.	Insp., S. Wales	Chief Insp., S. Wales	1-3-37
Tomlinson, F. S.	Insp., N. Western	Chief Insp., N. Western	19-2-37
Thompson, J.	Insp., N. Western	Chief Insp., N. Western	11-4-37
Outhwaite, W.	Insp., N.E. Reg.	Chief Insp., N.E. Reg.	26-3-37
Lewis, H. C.	Insp., S. Wales	Chief Insp., S. Wales	3-1-37
Eynott, F. C.	Insp., S. Eastern	Chief Insp., S. Eastern	18-10-36
Dilkes, G. H.	Insp., N. Midland	Chief Insp., N. Midland	14-3-37
Wardley, E. H.	Insp., N. Wales	Chief Insp., N. Wales	10-4-37
Livingstone, J.	Insp., Scot. Reg.	Chief Insp., Scot. Reg.	3-4-37
Taylor, W. H.	Insp., S. Midland	Chief Insp., S. Midland	28-3-37
Fletcher, J.	Insp., N.E. Reg.	Chief Insp., N.E. Reg.	18-4-37
Beughey, S. H.	Insp., London	Chief Insp., London	31-1-37
Baldwin, F.	Insp., N. Western	Chief Insp., N. Wales	2-5-37
Greene, A. H.	Insp., N.E. Reg.	Chief Insp., N.E. Reg.	4-4-37
Robertson, J.	Insp., Scot. Reg.	Chief Insp., Scot. Reg.	29-12-36
Lundy, E. H.	Insp., S. Lancs.	Chief Insp., S. Lancs.	12-1-37
Creed, H.	Insp., S. Eastern	Chief Insp., S. Eastern	1-12-36
Cooper, L. E.	Insp., S. Eastern	Chief Insp., S. Eastern	4-4-37
Janks, F. A. E.	Insp., S. Eastern	Chief Insp., S. Eastern	11-3-37
Mann, F.	Insp., Eastern	Chief Insp., Eastern	4-4-37
Shephard, A. C.	Insp., E.-in-C.O.	Chief Insp., E.-in-C.O.	6-2-37
Booth, G. W.	Insp., N.E. Reg.	Chief Insp., N.E. Reg.	18-4-37
Measey, W. F.	Insp., Scot. Reg.	Chief Insp., Scot. Reg.	5-3-37
Akester, G. B.	Insp., N.E. Reg.	Chief Insp., N.E. Reg.	21-3-37
Strong, H. A.	Insp., N. Midland	Chief Insp., N. Midland	1-7-37
Partington, B. G.	Insp., S. Lancs.	Chief Insp., S. Lancs.	21-3-37
Wright, T. D.	Insp., N. Wales	Chief Insp., N. Wales	24-1-37
King, R. R.	Insp., Eastern	Chief Insp., Eastern	4-4-37
Cross, W. H.	Insp., S. Lancs.	Chief Insp., S. Lancs.	1-4-37
Burnell, C. J.	Insp., London	Chief Insp., London	14-1-37
Steedman, C. A.	Insp., S. Midland	Chief Insp., S. Midland	20-3-37
Morrow, J. G. M.	Insp., N. Ireland	Chief Insp., N. Ireland	14-3-37
Lagne, J. H.	Insp., E.-in-C.O.	Chief Insp., E.-in-C.O.	7-2-37
Ware, W.	Insp., Test Section	Chief Insp., Test Sec., B'ham.	18-4-37
Hogbin, A.	Insp., E.-in-C.O.	Chief Insp., E.-in-C.O.	21-2-37
Madgwick, J. M.	Insp., N.E. Reg.	Chief Insp., N.E. Reg.	2-5-37
Pitloh, T. P.	Insp., N.E. Reg.	Chief Insp., N.E. Reg.	16-6-37
Dore, L. J.	Insp., N. Wales	Chief Insp., N. Wales	20-3-37
Barry, C.	Insp., N. Ireland	Chief Insp., N. Ireland	28-2-37
Howarth, H.	Insp., N. Western	Chief Insp., N.E. Reg.	2-5-37
Seymour, E. H.	Insp., London	Chief Insp., London	1-2-37
Rolin, F. W.	Insp., London	Chief Insp., London	8-11-36
Sharpe, H. T. A.	Insp., London	Chief Insp., London	1-2-37
Burrows, C. T.	Insp., S. Eastern	Chief Insp., S. Eastern	1-11-36
Hawkins, C. F. W.	Insp., London	Chief Insp., London	18-12-36
Sharpe, G. E.	Insp., N. Midland	Chief Insp., N. Midland	1-1-37
Owen, W.	Insp., S. Lancs.	Chief Insp., S. Lancs.	21-3-37
Love, R. C.	Insp., Scot. Reg.	Chief Insp., Scot. Reg.	5-3-37
Hoare, J. H.	Insp., S. Western	Chief Insp., S. Western	8-4-37
Chadwick, J.	Insp., S. Lancs.	Chief Insp., S. Lancs.	21-3-37
Trussler, H.	Insp., S. Western	Chief Insp., S. Western	10-1-37
Evans, W. P.	Insp., N. Wales	Chief Insp., N. Wales	20-3-37
Piggott, E. C. C.	Insp., N. Wales	Chief Insp., N. Wales	20-3-37
Blight, A.	Insp., London	Chief Insp., London	15-4-37
Gill, W. E	Insp., N. Midland	Chief Insp., N. Midland	29-12-36
Nixon, G.	Insp., N. Midland	Chief Insp., N. Midland	5-4-37
Winter, J. L.	Insp., N. Ireland	Chief Insp., N. Ireland	1-10-36
O'Roark, A. F.	Insp., N. Wales	Chief Insp., N. Wales	8-5-36
Deighton, C. F.	Insp., N.E. Reg	Chief Insp., N.E. Reg.	9-5-37
Sawyer, E. C.	Insp., S. Midland	Chief Insp., S. Western	2-5-37
Read, H.	Insp., S. Midland	Chief Insp., S. Midland	10-3-37

Name	From	To	Date
Norman, W. H. B. D.	Insp., London	Chief Insp., London	5-11-36
Arthur, C. S.	Insp., Scot. Reg.	Chief Insp., Scot. Reg.	28-2-37
Smith, R.	Insp., N.E. Reg.	Chief Insp., N.E. Reg.	27-5-37
Smith, J.	Insp., E.-in-C.O.	Chief Insp., N.E. Reg.	2-5-37
Gerrard, J.	Insp., E.-in-C.O.	Chief Insp., E.-in-C.O.	8-1-37
Gray, R. E.	Insp., S. Midland	Chief Insp., S. Western	9-5-37
Loveday, T. C.	Insp., Eastern	Chief Insp., Eastern	15-3-37
Broadhurst, S. W.	Insp., E.-in-C.O.	Chief Insp., E.-in-C.O.	27-9-36
Arthur, R.	Insp., Scot. Reg.	Chief Insp., Scot. Reg.	22-4-37
Thorne, E.	Insp., Eastern	Chief Insp., Eastern	14-2-37
Greenwood, E.	Insp., S Lancs.	Chief Insp., N. Wales	18-4-37
Griffiths, G. J.	Insp., N. Midland	Chief Insp., N. Midland	2-5-37
Margetts, A. W.	Insp., N. Wales	Chief Insp., N. Wales	20-3-37
Tunnicliff, T.	Insp., N. Wales	Chief Insp., N. Wales	20-3-37
Lamsden, R. S.	Insp., Scot. Reg.	Chief Insp., Scot. Reg.	15-11-36
Chance, A. H.	Insp., E.-in-C.O.	Chief Insp., E.-in-C.O.	27-9-36
Baird, E.	Insp., Scot. Reg.	Chief Insp., Scot. Reg.	18-4-37
Cork, E.	Insp., Eastern	Chief Insp., Eastern	20-12-36
Broad, W. H. G.	Insp., N. Wales	Chief Insp., N. Wales	20-3-37
Buy, H. A.	Insp., S. Midland	Chief Insp., S. Midland	21-3-37
Greenbury, L. J.	Insp., N.E. Reg.	Chief Insp., N.E. Reg.	8-1-37
Smith, C. N.	Insp., E.-in-C.O.	Chief Insp., Scot. Reg.	9-5-37
Proctor, F. H.	Insp., E.-in-C.O.	Chief Insp., E.-in-C.O.	26-3-37
Sherriff, L.	Insp., E.-in-C.O.	Chief Insp., E.-in-C.O.	1-4-37
Gilspin, H.	Insp., S. Midland	Chief Insp., S. Midland	18-4-37
Bull, S. W.	Insp., S. Western	Chief Insp., S. Western	13-1-37
Rhodes, W.	Insp., E.-in-C.O.	Chief Insp., E.-in-C.O.	20-3-37
Stewart, T.	Insp., E.-in-C.O.	Chief Insp., E.-in-C.O.	20-3-37
Pyman, F. A. M.	Insp., London	Chief Insp., London	15-4-37
Wooding, W. T.	Insp., London	Chief Insp., London	18-4-37
Hartshorn, H.	Insp., N.E. Reg.	Chief Insp., N.E. Reg.	30-5-37
Hasnip, A. G.	Insp., N. Midland	Chief Insp., N. Midland	14-3-37
Butcher, W.	Insp., N. Western	Chief Insp., N. Western	To be fixed later.
Carrette, A. D.	Insp., N.E. Reg.	Chief Insp., N.E. Reg.	15-3-37
Hamilton, D. F.	Insp., Scot. Reg.	Chief Insp., Scot. Reg.	14-4-37
Ellenden, A. H.	Insp., S. Eastern	Chief Insp., S. Eastern	9-5-37
Chapman, C. W.	Insp., S. Eastern	Chief Insp., S. Eastern	15-4-37
Whitmore, L. H.	Insp., S. Lancs.	Chief Insp., N. Midland	13-5-37
Boyd, W. J.	Insp., N. Ireland	Chief Insp., N. Ireland	20-9-36
Garner, J. E.	S.W.I., S. Lancs.	Insp., S. Lancs.	14-1-37
Hutton, R. W.	S.W.I., S. Lancs.	Insp., S. Lancs.	14-1-37
Hodson, G. H.	S.W.I., S. Lancs.	Insp., S. Lancs.	20-3-37
Oldam, J. W.	S.W.I., S. Eastern	Insp., S. Lancs.	27-3-37
Lane, W. J.	S.W.I., N.E. Reg.	Insp., N.E. Reg.	21-1-37
Vause, W. G.	S.W.I., N.E. Reg.	Insp., N.E. Reg.	19-12-36
James, J. K.	S.W.II., N.E. Reg.	Insp., N.E. Reg.	6-12-36
Haigh, S.	S.W.I., N.E. Reg.	Insp., N.E. Reg.	5-2-37
Vause, J. C.	S.W.I., N.E. Reg	Insp., N.E. Reg.	17-1-37
Townsend, E.	S.W.I., N.E. Reg.	Insp., N.E. Reg.	3-1-37
Sugden, E. C.	S.W.I., N.E. Reg.	Insp., N.E. Reg.	7-3-37
Wood, T.	S.W.I., N.E. Reg.	Insp., N.E. Reg.	7-3-37
Hawarth, J.	S.W.I., N. Western	Insp., N. Western	25-3-37
Parker, W.	S.W.I., N. Western	Insp., N. Western	1-2-37
Bew, G.	S.W.I., N.E. Reg.	Insp., N.E. Reg.	14-3-37
Little, J.	S.W.I., N.E. Reg.	Insp., N.E. Reg.	14-3-37
Pass, S.	S.W.I., N.E. Reg.	Insp., N.E. Reg.	14-3-37
Clark, E. A.	S.W.I., N.E. Reg.	Insp., N.E. Reg.	18-2-37
Gibson, W. R.	S.W.I., N.E. Reg.	Insp., N.E. Reg.	19-12-36
Bish, T. A.	S.W.I., N. Midland	Insp., N. Midland	13-9-36
Moss, J F.	S.W.I., N. Midland	Insp., N. Midland	17-4-37
Pacey, A. E.	S.W.I., N. Midland	Insp., N. Midland	3-1-37
Sheldrake, P.	S.W.I., N.E. Reg.	Insp., N.E. Reg.	25-3-37
Torbet, D. K.	S.W.I., N.E. Reg.	Insp., N.E. Reg.	14-3-37
Richardson, W. A.	S.W.I., N.E. Reg.	Insp., N.E. Reg.	1-4-37
Speechley, E.	S.W.I., N.E. Reg.	Insp., N.E. Reg.	21-3-37
Walker	S W.I., S. Lancs.	Insp., S. Lancs.	7-10-36
Bolus, E. H.	S.W.I., London	Insp., London	2-1-37
Brown, T. F. P.	S.W.I., London	Insp., London	2-1-37
Candish, P.	S.W.I. S. Eastern	Insp., S. Eastern	28-3-37
Cawte, H. M.	S.W.I , London	Insp., London	15-11-36
Chapman, B. E. J.	S.W.I., London	Insp., London	2-1-37
Church, W. H.	S.W.I., S. Eastern	Insp., S. Eastern	15-4-37
Collins, W. J.	S.W.I., London	Insp., London	8-11-36
Diprose, W. H.	S.W.I., London	Insp., London	1-8-36
Doyle, B. R. H.	S.W.I., London	Insp., London	18-12-36
Fagg, R. L.	S.W.I., S. Eastern	Insp., S. Eastern	3-5-37

Name	From	To	Date
Goff, A. A.	S.W.I., London	Insp., London	27-12-36
Gould, H.	S.W.I., London	Insp., London	2-12-36
Gransby, J. A.	S.W.I., London	Insp., London	2-1-37
Harvey, C. T.	S.W.I., London	Insp., London	5-1-37
Hewing, A. W.	S.W.I., London	Insp., London	1-11-37
Hewitt, W.	S.W.I., London	Insp., London	3-1-37
Hill, H. W.	S.W.II., London	Insp., London	1-10-36
James, J. R.	S.W.I., S. Eastern	Insp., S. Eastern	17-3-37
Kent, E. R.	S.W.I., S. Eastern	Insp., S. Eastern	9-5-37
King, J. W. G.	S.W.I., London	Insp., London	1-11-36
Leach, R. W.	S.W.I., London	Insp., London	5-12-36
March, S. W.	S.W.I., S. Eastern	Insp., S. Eastern	24-4-37
Nelson, L. W.	S.W.I., London	Insp., London	1-12-36
Osman, J. F.	S.W.I., London	Insp., London	12-1-37
Proudlove, R.	S.W.I., S. Eastern	Insp., S. Eastern	24-4-37
Sadler, G. E.	S.W.I., S. Eastern	Insp., S. Eastern	3-5-37
Sage, J. W.	S.W.I., London	Insp., London	2-1-37
Saunders, J. D.	S.W.I., S. Eastern	Insp., S. Eastern	5-4 37
Seal, E. E.	S.W.I., S. Eastern	Insp., S. Eastern	13-4-37
Smith, G. H.	S.W.II., London	Insp., London	19-9-36
Sparrowe, V. J.	S.W.I., S. Eastern	Insp., S. Eastern	18-10-36
Steadman, A.	S.W.II., London	Insp., London	18-9-36
Stevens, A. V.	S.W.I., London	Insp., London	5-1-37
Sudell, K.	S.W.I., S. Eastern	Insp., S. Eastern	28-3-37
Vickerage, H. B.	S.W.I., London	Insp., London	2-1-37
Videan, A. E.	S.W.I., S. East	Insp., S. Eastern	24-4-37
Wall, W. H.	S.W.I., London	Insp., London	21-11-26
Young, A. C.	S.W.I., S. Eastern	Insp., S. Eastern	14-4-37
Keen, S. R.	S.W.I., Rugby, R.S.	Insp., Rugby R.S.	1-1-37
Jose, V. W.	S.W.I., Rugby, R.S.	Insp., Rugby R.S.	1-1-37
Freeman, A. W.	S.W.I., Test Section, London	Insp., Test Section, London	To be fixed later.
Pearson, F. C.	S.W.I., Test Section, London	Insp., Test Section, London	To be fixed later.
Hudson, G. J.	S.W.I., Test Section, B'ham.	Insp., Test Section, B'ham.	To be fixed later.
Reynolds, W. H.	S.W.I., Test Section, B'ham.	Insp., Test Section, B'ham.	To be fixed later.
Faithfull, A. D.	S.W.I., S. Western	Insp., S. Western	13-3-37
Kallaway, H. N.	S.W.I., S. Western	Insp., S. Western	2-1-37
Martin, A. W.	S.W.I., S. Western	Insp., S. Western	1-9-36
Spencer, F. G.	S.W.I., S. Western	Insp., S. Western	18-10-36
Stephens, A. W.	S.W.I., S. Western	Insp., S. Western	2-5-37
Proctor, L.	S.W.I., S. Lancs.	Insp., S. Lancs.	9-1-37
Arundel, G.	S.W.I., N. Wales	Insp., N. Wales	10-11-36
Grant, L. E.	S.W.I., N. Wales	Insp., N. Wales	22-5-37
Genner, T.	S.W.I., N. Wales	Insp., N. Wales	6-2-37
Head, D. E.	S.W.I., N. Wales	Insp., N. Wales	20-10-36
Radford, W. E.	S.W.I., N. Wales	Insp., N. Wales	29-12-36
Rolls, A.	S.W.I., N. Wales	Insp., N. Wales	9-5-37
Russell, D. H.	S.W.I., N. Wales	Insp., N. Wales	10-12-36
Williams, A. V	S.W.I., N. Wales	Insp., N. Wales	20-9-36
Williams, R. V. C.	S.W.I., N. Wales	Insp., N. Wales	20-9-36
Allen, S. H.	S.W.I., S. Midland	Insp., S. Midland	1-5-37
Barnes, C. F.	S.W.I., S. Midland	Insp., S. Midland	8-5-37
Tuck, G. E.	S.W.I., S. Midland	Insp., S. Midland	1-11-36
Bellion, W. E.	S.W.I., S. Lancs.	Insp., S. Lancs.	6-1-37
Clarkson, W. J.	S.W.I., S. Lancs.	Insp., S. Lancs.	23-1-37
Halsall, N. J.	S.W.I., S. Lancs.	Insp., S. Lancs.	2-2-37
Jones, H.	S.W.I., S. Lancs.	Insp., S. Lancs.	16-2-37
Carter, A. T.	S.W.I., S. Lancs.	Insp., S. Lancs.	13-1-37
McWhirter, R. W.	S.W.I., N. Ireland	Insp., N. Ireland	2-10-36
Porter, J. M.	S.W.I., N. Ireland	Insp., N. Ireland	17-2-37
Goate, H. E.	S.W.I., Eastern	Insp., Eastern	20-12-36
Morris, R. J. H.	S.W.I., Eastern	Insp., Eastern	9-5-37
Rogers, F. P.	S.W.I., Eastern	Insp., Eastern	22-5-37
Banks, E. T.	S.W.I., Eastern	Insp., Eastern	1-9-36
Hawkins, W. E.	S.W.I., Eastern	Insp., Eastern	22-5-37
Harvey, J. H.	S.W.I., S. Lancs.	Insp., S. Lancs.	To be fixed later.
Naylor, A. G.	S.W.I., S. Lancs.	Insp., S. Lancs.	To be fixed later.
Arnold, W. S.	S.W.I., London	Insp., London	1-2-37
Bedford, A.	S.W.I., London	Insp., London	7-4-37
Bourne, E. J.	S.W.I., London	Insp., London	1-2-37
Edgar, A.	S.W.I., London	Insp., London	31-1-37
English, H. J.	S.W.I., London	Insp., London	3-4-37
Gadd, P. E.	S.W.I., London	Insp., London	10-1-37
Gale, C. S. M.	S.W.I., London	Insp., London	20-3-37
Garnett, J. A.	S.W.I., London	Insp., London	20-3-37
Harris, R. V.	S.W.I., London	Insp., London	6-4-37
Hayes, H. E.	S.W.I., London	Insp., London	8-1-37

Name	From	To	Date
Jones, A. E.	S.W.I., London	Insp., London	4-4-37
Springett, H. J. G.	S.W.I., London	Insp., London	16-1-37
Wright, J. R.	S.W.I., London	Insp., London	31-1-37
Clark, J. R.	S.W.I., N.E. Reg.	Insp., N.E. Reg.	30-5-37
Clement, C. M.	S.W.I., N. Western	Insp., N. Western	11-4-37
Ditchfield, J. A.	S.W.I., N. Western	Insp., N. Western	15-5-37
Watson, W. C.	S.W.I., N. Western	Insp., N. Western	21-5-37
Berry, A. B.	S.W.I., S. Wales	Insp., S. Wales	To be fixed later.
Clark, W. E	S.W.I., S. Wales	Insp., S. Wales	To be fixed later.
Jennings, A. R. E.	S.W.I., S. Wales	Insp., S. Wales	To be fixed later.
Jones, C. J.	S.W.I., S. Wales	Insp., S. Wales	To be fixed later.
O'Sullivan, P.	S.W.I., S. Wales	Insp., S. Wales	To be fixed later.
Phillips, C. G.	S.W.I., S. Wales	Insp., S. Wales	To be fixed later.
Scriven, G. H	S.W.I., S. Wales	Insp., S. Wales	To be fixed later.
Stephens, C. W.	S.W.I., S. Wales	Insp., S. Wales	To be fixed later.
Tovey, E. F.	S.W.I., S. Wales	Insp., S. Wales	To be fixed later.
Waite, W. C. H.	S.W.I., S. Wales	Insp., S. Wales	To be fixed later.
Brown, A.	S.W.I., Scot. Reg.	Insp., Scot. Reg.	25-4-37
Brown, W. H.	S.W.I., Scot. Reg.	Insp., Scot. Reg.	1-1-37
Brunton, J. B	S.W.I., Scot. Reg.	Insp., Scot. Reg.	25-1-37
Cameron, J. W.	S.W.I., Scot. Reg.	Insp., Scot. Reg.	15-5-37
Davidson, D.	S.W.I., Scot. Reg.	Insp., Scot. Reg.	4-1-37
Graham, J. M.	S.W.I., Scot. Reg.	Insp., Scot. Reg.	17-4-37
McCallum, A.	S.W.I., Scot. Reg.	Insp., Scot. Reg.	24-10-36
Manson, J. W.	S.W.I., Scot. Reg.	Insp., Scot. Reg.	20-3-37
Robertson, A.	S.W.I., Scot. Reg.	Insp., Scot. Reg	22-11-36
Wright, J.	S.W.I., Scot. Reg.	Insp., Scot. Reg.	3-12-36
Caterer, G. S	S.W.I., N. Midland	Insp., N. Midland	To be fixed later.
Taylor, A. A.	S.W.I., N. Midland	Insp., N. Midland	To be fixed later.
Grieve, W. S.	S.W.I., N. Ireland	Insp., N. Ireland	8-4-37
Fox, H. W.	S.W.I., N. Midland	Insp., N. Midland	To be fixed later.
Holland, R.	Draughtsman Cl. II., London	Draughtsman Cl. I., London	20-12-36
Hill, R.	Draughtsman Cl. II., N. Midland	Draughtsman Cl. I., S. Western	28-2-37
Wainwright, S. W.	Draughtsman Cl. II., S. Lancs.	Draughtsman Cl. I., S. Eastern	7-3-37
Joscelyne, S. G.	Draughtsman Cl. II., S. Wales	Draughtsman Cl. I., S. Wales	22-3-37
Jones, F. C.	Draughtsman Cl. II., Eastern	Draughtsman Cl. I., S. Wales	28-2-37
Sabine, D. C. W.	Draughtsman Cl. II., N. Wales	Draughtsman Cl. I., S. Western	21-3-37
Owles, F. H.	Draughtsman Cl. II., S. Eastern	Draughtsman Cl. I., S. Eastern	11-11-36
Cridland, J. F. S.	Draughtsman Cl. II., London	Draughtsman Cl. I., London	1-3-37
Barber, A.	Draughtsman Cl. II., London	Draughtsman Cl. I., S. Midland	11-4-37

RETIREMENTS.

Name	Rank	Location	Date
Hammond, G. W.	Asst. Suptg. Engr.	London	31-3-37
Stanton, J. D.	Exec. Engr	E.-in-C.O.	17-2-37
Hambleton, J. W.	Asst. Engr.	E.-in-C.O.	31-3-37
Graham, R. S.	Asst. Engr.	S. Lancs.	31-3-37
Akast, A. C. S.	Asst. Engr.	London	31-3-37
Garnett, J. A.	Asst. Engr.	London	31-3-37
Wood, W.	Chief Insp.	S. Lancs.	31-3-37
Warren, H. J.	Chief Insp.	N. Midland	4-4-37
Britton, F. W.	Chief Insp.	Test Section, B'ham.	28-2-37
Tott, W. J.	Insp	Test Section, London	5-2-37
O'Connor, W.	Insp.	Scot. Reg.	16-4-37
Wheatley, J. J	Insp.	London	30-4-37
Lewin, J. G.	Insp.	London	30-4-37
Butler, W. T.	Insp.	London	30-4-37
Goldsmith, T.	Insp.	S. Western	5-5-37
Webb, H. J.	Insp.	London	9-6-37
Smith, A. C.	Draughtsman Cl. I.	E.-in-C.O.	5-2-37

DEATHS.

Name	Rank	District	Date
Mentasti, R. G. B.	Insp.	S. Lancs.	21-3-37
Ringrose, T. H.	Insp.	London	1-4-37
O'Connor, H.	Insp	Scot. Reg.	5-4-37
Harrison, J	Insp.	S. Lancs.	25-5-37
Standing, J.	Insp.	S. Lancs.	25-5-37

Name	From	To	Date
Blackstaffe, H. P.	Snr. Draughtsman E.-in-C.O	Asst Engr., E -in-C O.	6-4-37
Trueman, G. F.	Proby. Insp , S. Lancs.	Insp., S. Lancs	1-6-37
Bun, D. W.	Proby. Insp., London	Insp., London	1-6-37
Wells, L. A.	Proby. Insp., London	Insp., London	1-6-37
Bird, J.	Proby. Insp., Eastern	Insp , Eastern	1-6-37
Wells, H. M.	Proby. Insp., E.-in-C.O.	Insp., E.-in-C.O.	1-6-37
Humphreys, L. W	Proby. Insp., E.-in-C.O.	Insp., E.-in-C.O.	1-6-37
Clifford, F. G.	Proby. Insp., E.-in-C.O.	Insp., E.-in-C.O.	1-6-37
Chilver, L. W. J.	Proby. Insp , London	Insp., London	1-6-37
Winkley, W. J. F.	Proby. Insp., Eastern	Insp., Eastern	1-6-37
Spratley, E. W. F.	Proby. Insp., E.-in-C.O.	Insp., E.-in-C.O.	1-6-37
Kenner, S.	Proby. Insp., London	Insp., London	1-6-37
Walters, J. R.	Proby. Insp., S. Midland	Insp., S. Midland	1-6-37
Arthur, J. C. C	Proby. Insp., London	Insp., London	1-6-37
Moffatt, J. J.	Proby. Insp., London	Insp., London	1-6-37
Sawyers, L. F.	Proby. Insp., S. Midland	Insp., S. Midland	1-6-37
Kent., S. T. E.	Proby. Insp., London	Insp., London	1-6-37
Russell, A. R.	Proby. Insp., London	Insp., London	1-6-37
Halton, T. J. V	Proby. Insp., S. Lancs.	Insp., S. Lancs.	1-6-37
Brian, R. H.	Proby. Insp., N. Midland	Insp., N. Midland	1-6-37
Smith, N. D.	Proby. Insp., E.-in-C.O.	Insp., E.-in-C.O.	1-6-37
Dennis, H.	Proby. Insp., N. Midland	Insp., N. Midland	1-6-37
Mead, A. C.	Proby. Insp., London	Insp., London	1-6-37
Stevens, S. T.	Proby. Insp., N. Wales	Insp., N. Wales	1-6-37
Batt, T. D.	Proby. Insp., Eastern	Insp., Eastern	1-6-37
Alexander G. E	Proby. Insp., London	Insp., London	1-6-37
Milton, A. G.	Proby. Insp., London	Insp., London	1-6-37
Barnsdall, L. G W.	Proby. Insp., N. Midland	Insp., N. Midland	1-6-37
Baxter, E. C.	Proby. Insp., London	Insp., London	1-6-37
Charles, E. E.	Proby. Insp., N. Wales	Insp., N. Wales	1-6-37
Morgan, J. L. W	Proby. Insp., E.-in-C.O.	Insp., E.-in-C.O.	1-6-37
Easton W.	Proby. Insp., S. Wales	Insp., S. Wales	1-6-37
Smith, J. R. G.	Proby. Insp., London	Insp., London	1-6-37
Phillips, H. A.	Proby. Insp., S. Western	Insp., S. Western	1-6-37
Groves, F. W.	Proby. Insp., London	Insp., London	1-6-37
Kelly, F.	Proby. Insp., S. Lancs.	Insp., S. Lancs.	1-6-37
Varney, R. E. H.	Proby. Insp., N. Wales	Insp., N. Wales	1-6-37
Eustace, J.	Proby. Insp., London	Insp., London	1-6-37
Hayward, R. W.	Proby. Insp., S. Midland	Insp., S. Midland	1-6-37
Barber, B. D.	Proby. Insp., S. Eastern	Insp., S. Eastern	1-6-37
Smart, J. H. C.	Proby. Insp., S. Lancs	Insp., S. Lancs.	1-6-37
Richardson, C. A.	Proby. Insp., London	Insp., London	1-6-37
Fuller, W.	Proby. Insp., London	Insp , London	1-6-37
Freeman J. H.	Proby. Insp., London	Insp., London	1-6-37
Turner, E.	Proby. Insp., N. Wales	Insp., N. Wales	1-6-37
Laver, K. S.	Proby. Insp., Eastern	Insp., Eastern	1-6-37
Oakford, E. R.	Proby. Insp., London	Insp., London	1-6-37
Moore, S. J.	Proby. Insp., S. Western	Insp., S. Western	1-6-37
Laver, F. J. M.	Proby. Insp., E.-in-C.O.	Insp., E-.in-C.O.	1-6-37
Bomford, K. D.	Proby. Insp., E.-in-C.O.	Insp., E.-in-C.O.	1-6-37
Morris, O. W.	Proby. Insp., E.-in-C.O.	Insp., E.-in-C.O.	1-6-37
Harris, R. J.	Proby. Insp., E.-in-C.O.	Insp., E.-in-C.O.	1-6-37
Hayman, H. W. G.	Proby. Insp., S.Western	Insp., S. Western	1-6-37
Broad, E. R.	Proby. Insp., E.-in-C.O.	Insp., E.-in C.O.	29-6-37
Richards, C. W. C.	Proby. Insp., S. Wales	Insp , S. Wales	1-7-37
Richards, D. L.	Proby. Insp., E.-in-C.O.	Insp., E. in C.O.	20-7-37
Greenman, L. H.	Proby. Insp., S. Lancs.	Insp., S. Lancs.	1-6-37
Cheek, P.	Proby. Insp., E.-in-C.O	Insp., E.-in-C.O.	4-6-37
Bray, P. R.	Proby. Insp., E.-in-C.O.	Insp., E.-in-C.O.	8-7-37
Marshman, R. C.	Proby. Insp., N.E. Reg.	Insp., N.E. Reg.	24-6-37
Lamb, A. H.	Proby. Insp., N.E. Reg.	Insp., N.E. Reg.	1-6-37
Branston, E. C.	Proby. Insp., N.E. Reg.	Insp., N.E. Reg.	1-6-37
Lauderdale, T. S.	Proby. Insp., N.E. Reg.	Insp., N.E. Reg.	1-6-37
Wadeson, D. E.	Proby. Insp., Scot. Reg.	Insp., Scot. Reg.	1-6-37
McEachan, J.	Proby. Insp., Scot. Reg.	Insp.,,Scot. Reg.	1-6-37
Loughlin, J. J.	Proby. Insp., Scot. Reg	Insp., Scot. Reg.	1-6-37
McMillan, T. A.	Proby. Insp., Scot. Reg.	Insp., Scot. Reg.	1-6-37
Macpherson, A.	U.S.W., S. Midland	Proby. Insp., E.-in-C.O.	1-5-37
Blanchard, J. A.	U.S.W., N.E. Reg.	Proby. Insp., E.-in-C.O.	1-5-37
Burchell, J. R. L.	U.S.W., London	Proby. Insp., E.-in-C.O.	1-5-37
Jones, D. C.	U.S.W., E.-in-C.O.	Proby. Insp., E.-in-C.O.	1-5-37
Burstow, A. S.	U.S.W., London	Proby. Insp., E.-in-C.O.	1-5-37
Wilson, J. C.	U.S.W., London	Proby. Insp., E.-in-C.O.	1-5-37
Whittaker, E. N.	U.S.W., N. Midland	Proby. Insp., E.-in-C.O.	1-5-37
Johnson, D. E. N.	U.S.W., Scot. Reg.	Proby. Insp., E.-in-C.O.	1-5-37
Linney, H. H.	U.S.W., S. Lancs.	Proby. Insp., E.-in-C.O.	1-5-37

Name	From	To	Date
Galloway, J.	U S.W , S. Lancs.	Proby. Insp., E.-in-C.O.	1-5-37
Stubbington, C. J	—	Proby. Insp., E -in-C.O.	10-5-37
Tressider, W. M.	U.S.W., E.-in-C.O	Proby. Insp., E.-in-C.O.	1-5-37
Neal, N. W.	U.S.W., E.-in-C.O.	Proby. Insp., E.-in-C.O.	1-5-37
Walker, E. H.	—	Proby. Insp., E.-in-C.O.	19-5-37
Davies, L. J. D.	—	Proby. Insp., E.-in-C.O.	5-5-37
Bowers, F	—	Proby. Insp., E.-in-C.O.	1-5-37
Reid, H. A.	—	Proby. Insp., E.-in-C.O.	1-5-37
Wooster, C. B.	Youth, Eastern	Proby. Insp., E.-in-C.O.	1-5-37
Mackereth, W. W.	—	Proby. Insp., E -in-C.O.	1-5-37
Garnett, W. H.	U.S.W., London	Proby. Insp., E.-in-C.O.	1-5-37
Norfolk, J. D.	—	Proby. Insp., E.-in-C.O.	3-5-37
Saxey, A. E.	—	Proby. Insp., E.-in-C.O.	25-5-37
Reeves, L. N.	—	Proby. Insp., E -in-C.O.	1-5-37
Wilshaw, G. W.	—	Proby. Insp., E.-in-C.O.	20-5-37
Peet, H.	—	Proby. Insp., E.-in-C.O.	29-5-37
Soames, G. A.	—	Proby. Insp., E.-in-C.O.	3-5-37
Carnson, L. B.	U.S.W., S. Lancs.	Proby. Insp., E.-in-C.O.	22-5-37
Pearce, H. J.	—	Proby. Insp., E.-in-C.O.	31-5-37
Hunt, A. H.	U.S.W., N.E. Reg.	Proby. Insp., E.-in-C.O.	3-5-37
Hackett, S. B.	—	Proby. Insp., E.-in-C.O.	To be fixed later.
Bailey, N. G.	—	Proby. Insp., E.-in-C.O.	1-5-37
Lewis, H.	—	Proby. Insp., E.-in.C.O.	26-5-37
Marks, D. J.	—	Proby. Insp., E.-in-C.O.	1-5-37
Hix, K. W.	—	Proby. Insp., E.-in-C.O.	To be fixed later.
Gordon, S. C.	—	Proby. Insp., E.-in-C.O.	8-5-37
Bailey, E. E.	—	Proby. Insp., E.-in-C.O.	24-5-37
Moody, P. H.	—	Proby. Insp., E.-in-C.O.	1-5-37
Wharhirst, C. J.	—	Proby. Insp., E.-in-C.O.	1-5-37
Harvey, A. G.	—	Proby. Insp., E.-in-C.O.	3-5-37
Yemm, H.	—	Proby. Insp., E.-in-C.O.	1-5-37
Dafforn, D. G.	U.S.W., London	Proby. Insp., E.-in-C.O.	1-5-37
Palmer, J. E.	—	Proby. Insp., E.-in-C.O.	15-8-37
Lane, G. W. H.	—	Proby. Insp., E.-in-C.O.	1-5-37
Slingo, F. W.	U.S.W., S. Eastern	Proby. Insp., E.-in-C.O.	1-5-37
Ward, C. V.	—	Proby. Insp., E.-in-C.O.	3-5-37
Lee, L. R.	—	Proby. Insp., E.-in-C.O.	10-5-37
Saunders, J. C.	—	Proby. Insp., E.-in-C.O.	1-5-37
Oxlade, W. J.	U.S.W., London	Proby. Insp., E.-in-C.O.	1-5-37
Hunt, C. S.	U.S.W., London	Proby. Insp., E.-in-C.O.	1-5-37
Perkins, D. G.	U.S.W., London	Proby. Insp., London Postal Reg.	1-5-37
Bennett, G.	U.S.W., N.E. Reg.	Proby. Insp., E.-in-C.O.	1-5-37
Keep, J. F.	U.S.W., London	Proby. Insp., E.-in-C.O.	1-5-37
Skuse, C. E. C.	Draughtsman II, London	Proby. Insp., E.-in-C.O.	1-5-37
Wright, G.	U.S.W., S. Lancs.	Proby. Insp., E -in-C.O.	1-5-37
Peck, D. G.	U.S.W., N. Ireland	Proby. Insp., E.-in-C.O.	1-5-37
Gaudsen, S. H.	U.S.W., London	Proby. Insp., E.-in-C.O.	1-5-37
Sanders, F. S. B.	U.S.W., E.-in-C.O.	Proby. Insp., E.-in-C.O.	1-5-37
Masdin, R. M.	U.S.W., E.-in-C.O.	Proby. Insp., E.-in-C.O.	1-5-37
Harvey, V. J.	U.S.W., Test Section, London	Proby. Insp., E.-in-C.O.	1-5-37
Unwin, J. H.	U.S.W., London	Proby. Insp., E.-in-C.O.	1-5-37
Stafford, L.	U.S.W., Test Section, B'ham.	Proby. Insp., E.-in-C.O.	1-5-37
Powell, G. F.	U.S.W., S. Lancs.	Proby. Insp., E.-in-C.O.	1-5-37
Seager, E. F.	U.S.W., London	Proby. Insp., E.-in-C.O.	1-5-37
Upchurch, S. W. J.	U.S.W., London	Proby. Insp., E.-in-C.O.	1-5-37
Lunt, L. S.	U.S.W. Test Section, B'ham.	Proby. Insp., E.-in-C.O.	1-5-37
Stewart, W. F. G	U.S.W., Scot. Reg.	Proby. Insp., E.-in-C.O.	1-5-37
Smith, A. F. C.	U.S.W., London	Proby. Insp., E.-in-C.O.	1-5-37
Chant, L.	U.S.W., London	Proby. Insp., E.-in-C.O.	1-5-37
Lennard, G. F.	U.S.W., London	Proby. Insp., E.-in-C.O.	1-5-37
Hales, J. T.	U.S.W., St. Albans, R.S.	Proby. Insp., E.-in-C.O.	1-5-37
Flavell, J. A.	U.S.W., London	Proby. Insp., E.-in-C.O.	1-5-37
Tough, J. L.	U.S.W., S. Western	Proby. Insp , E.-in-C.O.	1-5-37
Eccles, J.	U.S.W., London	Proby. Insp., E.-in-C.O.	1-5-37
Sheppard, J.	U.S.W., London	Proby. Insp., E.-in-C.O.	1-5-37
Venus, A. L.	U.S.W., London	Proby. Insp., E.-in-C.O.	1-5-37
King, E. S. F.	—	Proby. Insp , E.-in-C.O.	1-5-37
Waldram, A. H. T.	—	Proby. Insp., E.-in-C.O.	To be fixed later.
Davidson, C. F.	—	Proby. Insp., E.-in-C.O.	8-5-37
Gates, R. E.	Youth, S. Lancs.	Proby. Insp., E.-in-C.O.	1-5-37
Burley, N.	—	Proby. Insp., E.-in-C.O.	6-5-37
Mills, R. J.	—	Proby. Insp., E.-in-C.O.	1-5-37
Percival, F. V.	—	Proby. Insp., E.-in-C.O.	1-6-37
Phillips, G. J. A	—	Proby. Insp., E.-in-C.O.	4-5-37
Roberts, F. F.	—	Proby. Insp., E.-in-C.O.	1-5-37
Haworth, J. E.	U.S.W., E.-in-C.O.	Proby. Insp., E.-in-C.O.	1-5-37

Name	From	To	Date
Ansell, G. V.	—	Proby. Insp., E.-in-C.O.	4-5-37
Thompson, J	—	Proby. Insp., E.-in-C.O.	3-5-37
Stead, L. G.	U.S.W., London	Proby. Insp., E.-in-C.O.	1-5-37
Burton, R. N.	—	Proby. Insp., E.-in-C.O	10-5-37
Longyear, J. W	—	Proby. Insp., E.-in-C.O	To be fixed later.
Littler, C.	—	Proby. Insp., E.-in-C.O	1-5-37
Emms, W. G.	—	Proby. Insp., E.-in-C.O	8-5-37
Rossiter, G. E.	U.S.W., E.-in-C.O	Proby. Insp., E.-in-C.O	1-5-37
Parker, P. N.	—	Proby. Insp., E.-in-C.O	1-5-37
Alston, R. E.	—	Proby. Insp., E.-in-C.O	To be fixed later.
Roberts, T. N. D	—	Proby. Insp., E.-in-C.O	1-5-37
Croft, E.	—	Proby. Insp., E.-in-C.O	4-5-37
Boyle, C.	—	Proby. Insp., E.-in-C.O	10-5-37
Bailey, C. W.	—	Proby. Insp., E.-in-C.O	To be fixed later.
Norman, J. M	U.S.W., London	Proby. Insp., E.-in-C.O	1-5-37
Moorcroft, H C	—	Proby. Insp., E.-in-C.O	1-5-37
Cobbe, B. M.	U.S.W., Eastern	Proby. Insp., E.-in-C.O	1-5-37
Hulme, R.	Youth, N. Western	Proby. Insp., E.-in-C.O	5-5-37
Rimmer, E. G	—	Proby. Insp., E.-in-C.O	7-5-37
Eley, A. C.	—	Proby. Insp., E.-in-C.O	1-5-37
Heath, K.	U.S.W., N E Reg.	Proby. Insp., E.-in-C.O	1-5-37
Row, L. N.	—	Proby. Insp., E.-in-C.O	1-5-37
Bourne, K. W.	—	Proby. Insp., E.-in-C.O	24-5-37
Home, J. K.	U.S.W., S. Western	Proby. Insp., E.-in-C.O	1-5-37
Croisdale, A. C.	—	Proby. Insp., E.-in-C.O	10-5-37
Griffiths, D. A. C	—	Proby. Insp., E.-in-C.O	10-5-37
Astle, E.	—	Proby. Insp., E.-in-C.O	10-5-37
Harris, D. J.	—	Proby. Insp., E.-in-C.O	To be fixed later.
Light, R. W.	—	Proby. Insp., E.-in-C.O	1-5-37
Bennett, R. O.	—	Proby. Insp., E.-in-C.O	3-5-37
Hankin, B. D.	Youth, London	Proby. Insp., E.-in-C.O	1-5-37
Thorne, N. W.	—	Proby. Insp., E.-in-C.O	1-5-37
Butland, T. K.	—	Proby. Insp., E.-in-C.O	1-5-37
Woodford, R. A	—	Proby. Insp., E.-in-C.O	1-5-37
Goldsmith, F. H	—	Proby. Insp., E.-in-C.O	14-5-37
Farrow, C. F.	—	Proby. Insp., E.-in-C.O	1-5-37
Mole, H. H. R.	—	Proby. Insp., E.-in-C.O	1-5-37
Lawson, R.	—	Proby. Insp., E.-in-C.O.	3-5-37
Sinnicks, A. C.	—	Proby. Insp., E.-in-C.O	8-5-37

The Board of Editors is not responsible for the statements made or the opinions expressed in any of the articles in this Journal, unless such statement is made specifically by the Board.

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: NATional 6321. Remittances should be made payable to "*The P.O.E.E. Journal*" and should be crossed "& Co."

Binding Cases

Binding cases are available, and may be obtained from the Local Agents for 1s. 9d. Subscribers can have their copies of Volumes bound, at a cost of 3s., by sending the complete sets of parts to the Local Agents or to the Publishers. 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 will be 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.), Station Road, Epsom, Surrey.

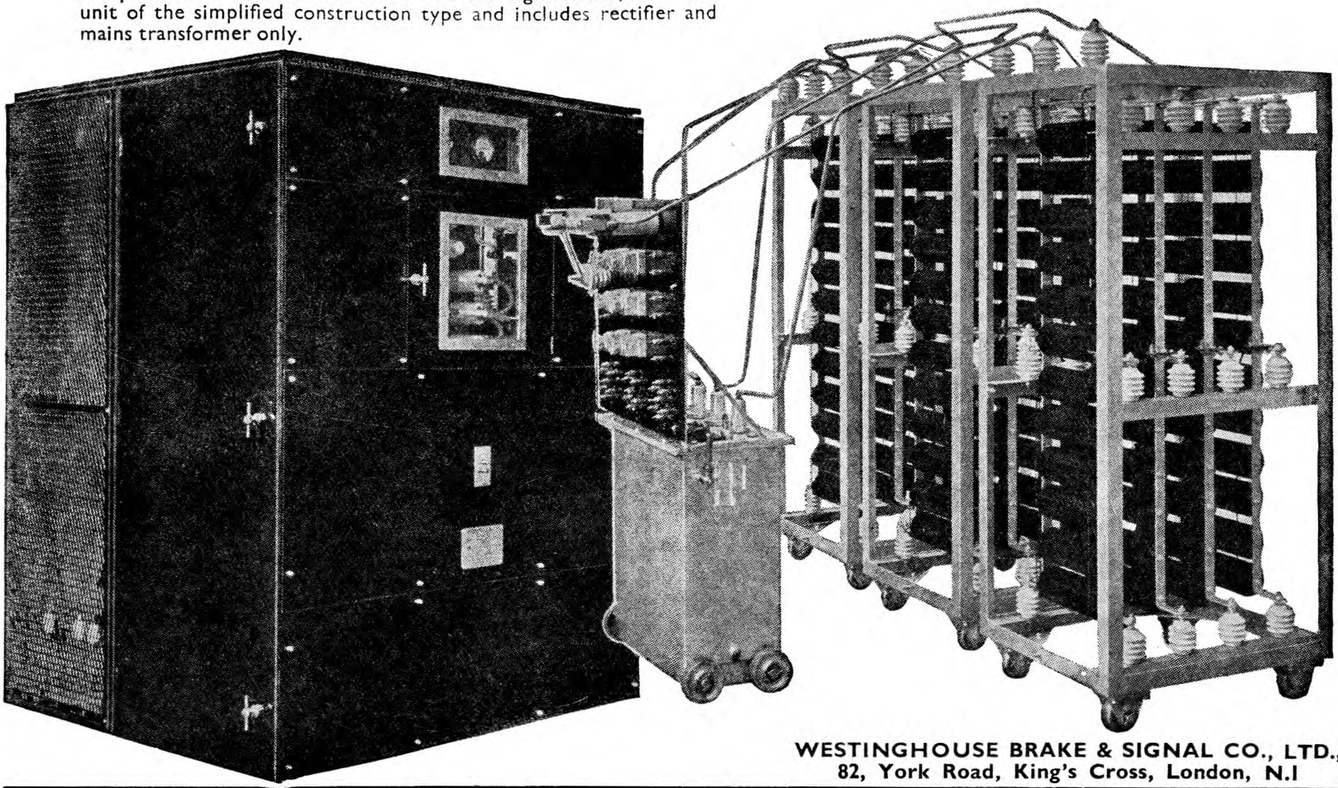
ATTENTION *nil!*

No Maintenance No Renewals

A Westinghouse Metal Rectifier and smoothing circuit has the great advantage that it is a static apparatus requiring no attention, maintenance or renewal. Its action is instantaneous. It can be supplied with special finish to match the remainder of the equipment, or as a simple rectifier and mains transformer unit without case.

WESTINGHOUSE METAL RECTIFIERS

Above is illustrated an H.T. supply unit with an output of 6,000 volts 1 A, smoothed 0.03 per cent. ripple, supplied to the New Zealand Government. This type is specially finished to match the radio equipment, and includes rectifier, mains transformer and full protective and alarm circuits. On the right is a 5,000 V 2 A unit of the simplified construction type and includes rectifier and mains transformer only.



WESTINGHOUSE BRAKE & SIGNAL CO., LTD.,
82, York Road, King's Cross, London, N.1

CHANGING LONDON

When man first discovered that the River Thames could be forded at that spot the tale of London commenced, and since then it has been nearly 2,000 years in the telling. London River, as the sailors call it, has always figured prominently in the story, for the port made the capital, although the capital has since helped the port to flourish. That London is the financial centre of the world is largely due to the volume and importance of the port's trade. Export and import values, for example, total some £450,000,000 per year—and this figure represents not one or two specialized commodities, but the trade of the nation. Goods to and from every country are constantly entering or leaving the port, and consequently the Bill of Exchange on London is negotiable all over the world.

Chief port—centre of finance—seat of Government—in this great city telephone service must be of the highest possible standard. Only automatic telephone equipment can achieve the consistent speed and accuracy necessary, and the British Post Office some years ago standardised the Strowger system for all future use. The process of automatisation, and the growth of London's telephone communication facilities generally, are depicted on the Charts.

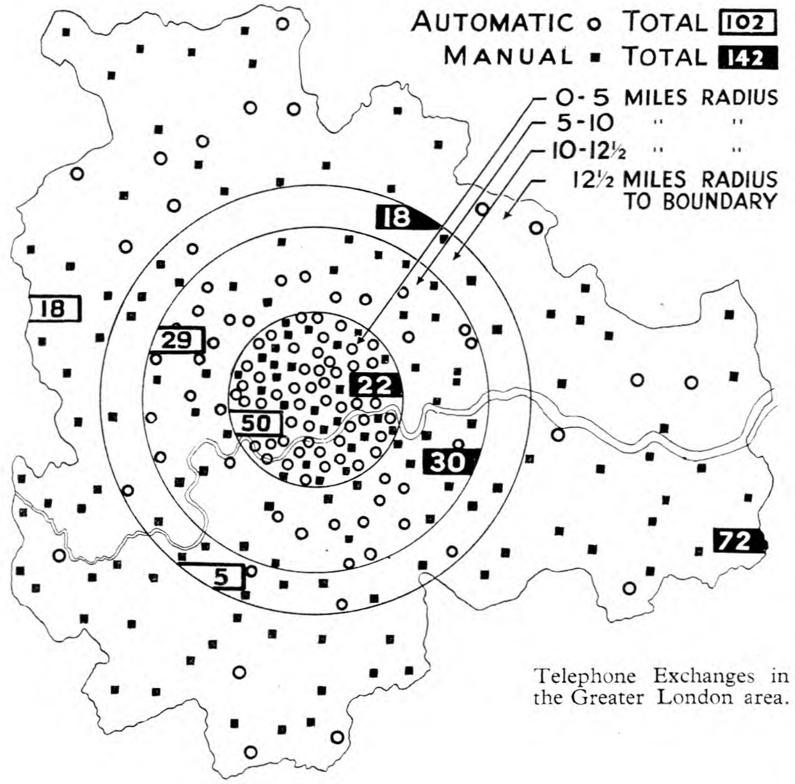
ATM
REGD. TRADE MARK

AUTOMATIC TELEPHONE & ELECTRIC CO., LTD.

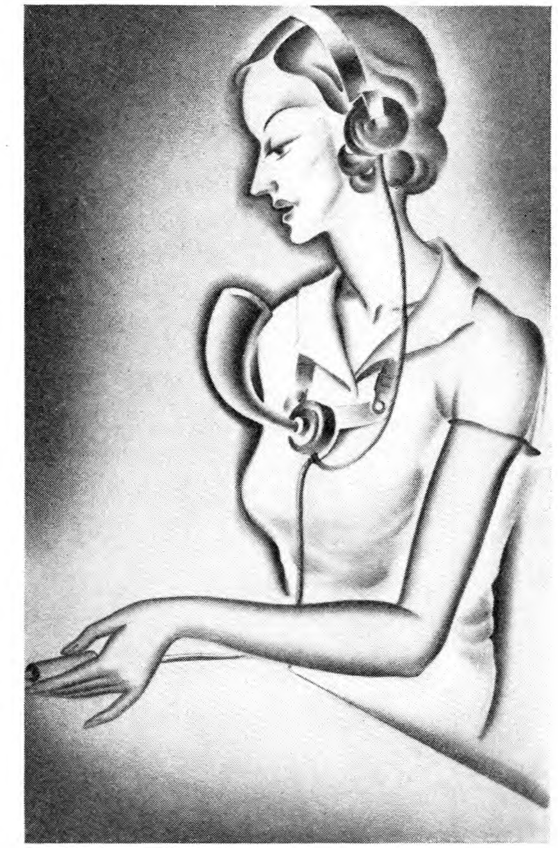
MELBOURNE HOUSE · ALDWYCH · W.C.2
Telephone : Temple Bar 4506 — Telegrams : "Strowger, Estrand, London"

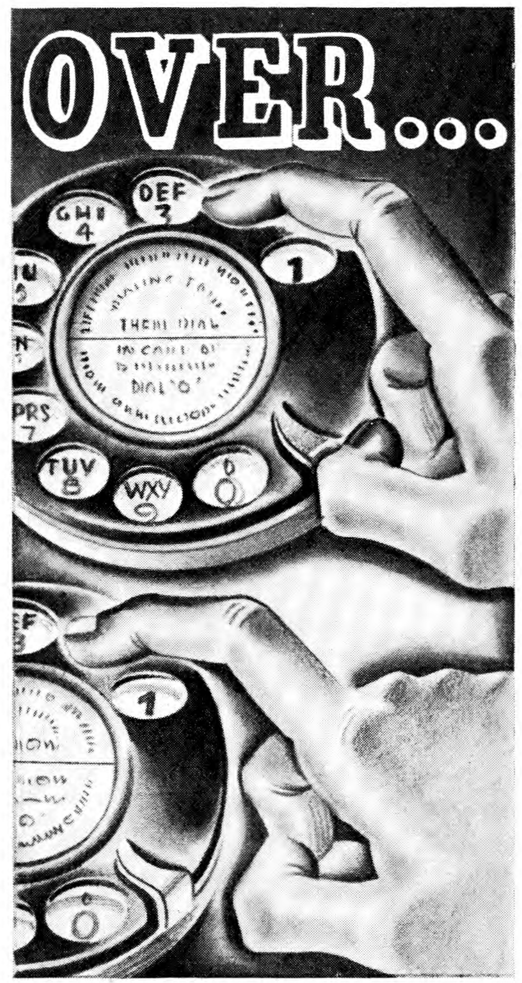
Export Office : NORFOLK HOUSE, NORFOLK STREET, W.C.2
Telephone : Temple Bar 9262 — Telegrams : "Autelco, Estrand"

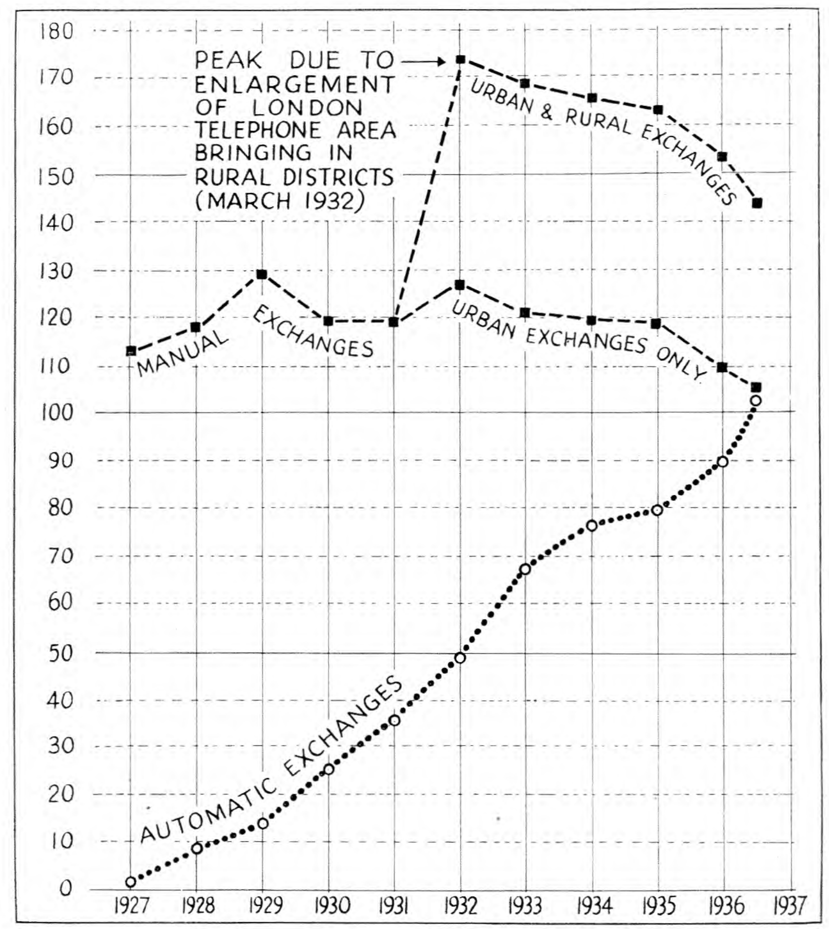
STROWGER WORKS · LIVERPOOL, 7
Telephone : Old Swan 830 — Telegrams : "Strowger, Liverpool"



Telephone Exchanges in the Greater London area.







CONTRACTORS TO THE GENERAL POST OFFICE

TUNGSTONE

STORAGE BATTERIES
FOR
Central Stations · Works · House Lighting

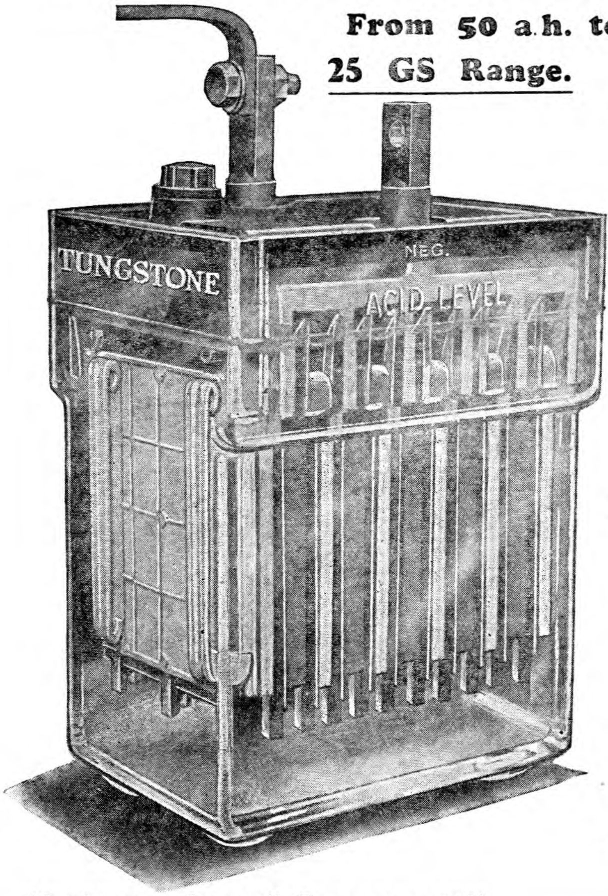
Entirely of British Origin and Workmanship. British Empire Lead exclusively used.

THE INDEPENDENT BATTERY OF THE BRITISH EMPIRE

Enclosed or Sealed type Planté Cells

From 50 a.h. to 125 a.h. Capacities at 10 hr. Rate.

25 GS Range.



Height over Intercell Connectors 16⅞″.

Constructed to conform to British Standard Specification.

All Plates are built under our Standard High Pressure Machine Die-Cast process, guaranteeing Maximum Storage Capacity and longest working life.

Positive Plates. Very heavy Planté Type. 4⅞″ wide, 6½″ deep, 12 m/m thick.

Negative Plates. BoxType, 4⅞″x6½″ deep, 8 m/mthick.

Separators. Specially treated Port Orford Cedar, suspended from the top of plates leaving space clear at bottom of Cell.

Containers. Strong glass with heavy plate supports. Positive and Negative terminal positions clearly marked and acid-level shown all round Cell.

Assembly. Cells are supplied fully assembled. Positive and Negative lug pillars of different height prevent wrongly connecting up. Lead covered bolts, and nuts and lead washers supplied. End springs are secured in position on the negative plates.

All enclosed type Cells can be delivered filled with acid and fully charged for immediate use.

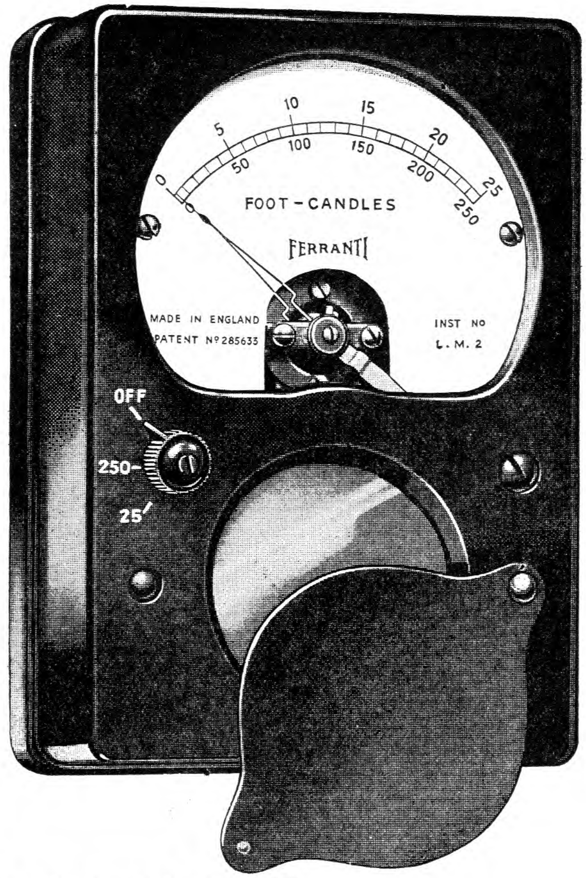
Type No.	A.H. Capacity	Charging Rates		Discharge Rates in Amperes			Weight of Cell Filled	Quantity of Acid per Cell	External Dimensions of Cell			Pitch of Cells
		Normal	Max.	10 Hours	5 Hours	1 Hour			Length	Width	Height	
							lbs.	gallons	inches			
25G5S	50	7	11	5	8.5	25	37	.62	5⅛	7⅞	12½	5½
25G7S	75	11	16	7.5	12.5	37.5	52	.80	6⅝	7⅞	12½	7
25G9S	100	14	21	10	16.5	50	63	1.1	8⅛	7⅞	12½	8½
25G11S	125	18	27	12.5	21	62.5	74	1.2	9⅝	7⅞	12½	10

The Plate is the Nerve Centre of any Battery

TUNGSTONE ACCUMULATOR CO., LTD., St. Bride's House, Salisbury Square, E.C.4

Telephone: CENTRAL 8156 (4 lines) & 8189 Telegrams: "Typify, Fleet, London." Cables: "Dilutum, London"

INDEX TO ADVERTISERS


0
5
10
15
20
25
50
100
150
200
250
FOOT-CANDLES
FERRANTI
MADE IN ENGLAND
PATENT Nº 285633
INST NO
L. M. 2
OFF
250-
25

Printed by SANDERS PHILLIPS & CO., LTD., The Baynard Press, Chryssell Road, London, S.W.9, and Published by BIRCH & WHITTINGTON (*Prop. Dorling & Co. [Epsom] Ltd.*), Station Road, Epsom, Surrey.