THE POST OFFICE ELECTRICAL ENGINEERS' JOURNAL

VOL. 32 JULY, 1939 PART 2

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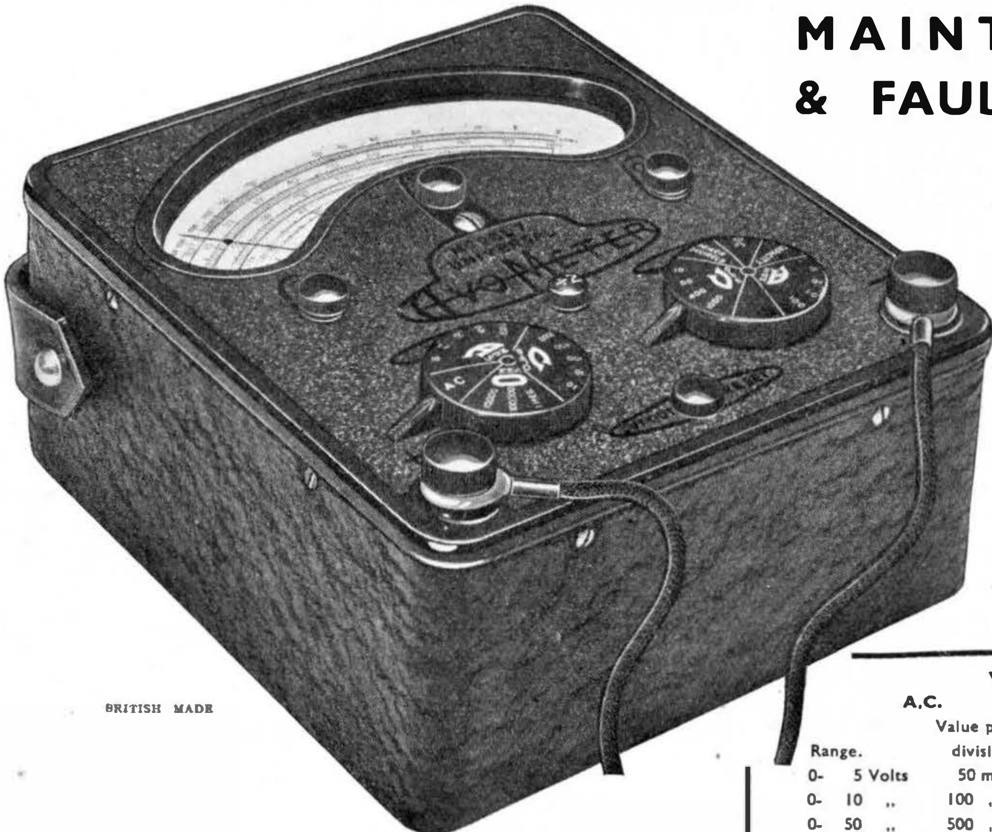

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0- 50 ,,	500 ,,
0- 100 ,,	1 Volt
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0-100 ,,	1 mA
0-500 ,,	5 ,,
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0- 5 ,,	50 ,,
0- 10 ,,	100 ,,

D.C.

Range	Value per division
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0- 2 ,,	20 ,,
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0- 10 ,,	100 ,,
0- 50 ,,	500 ,,
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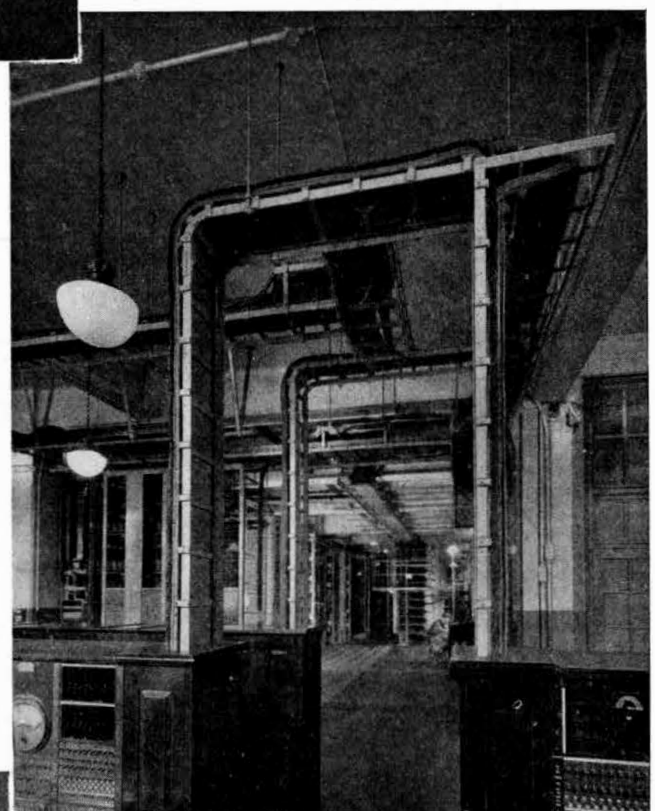

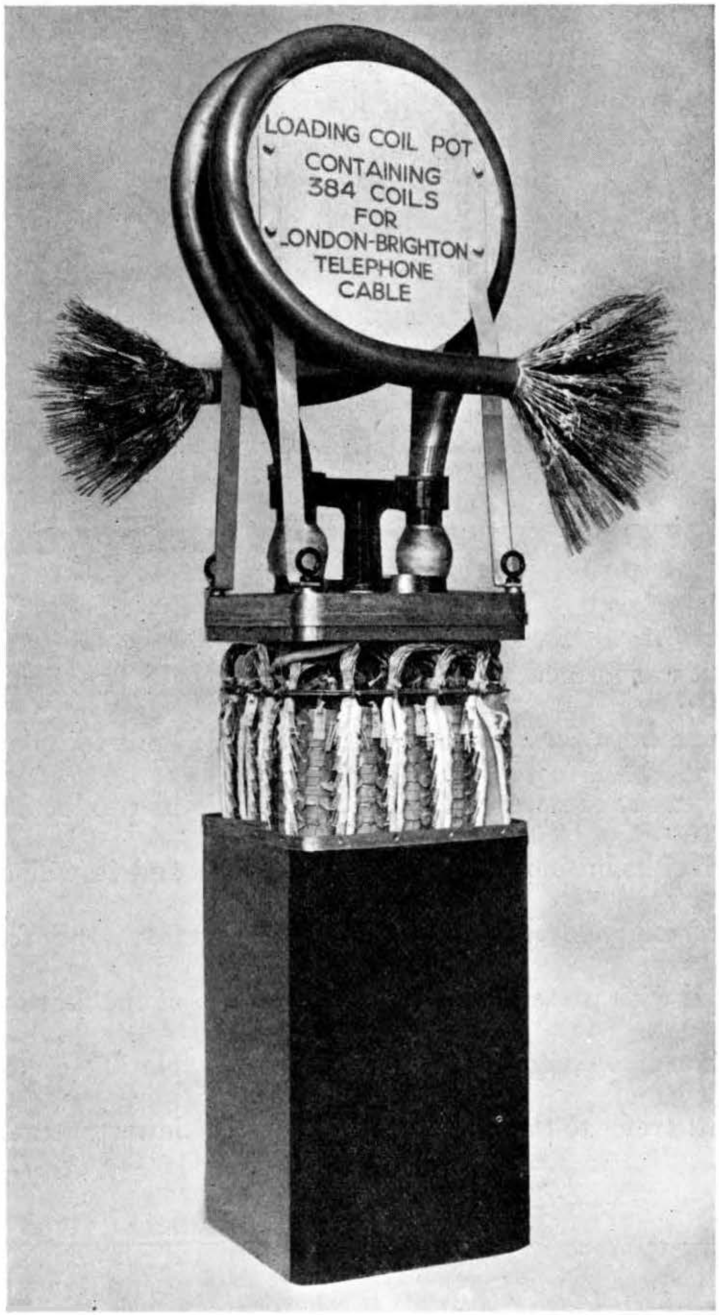
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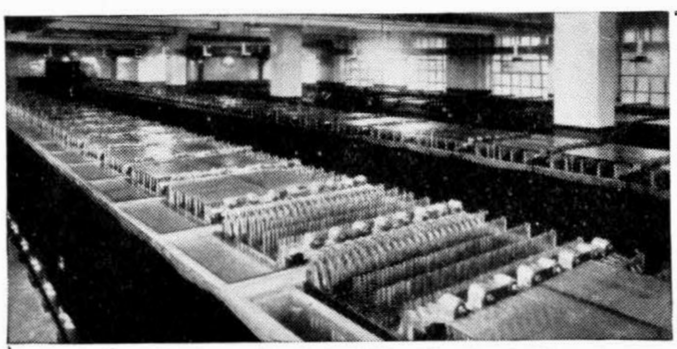

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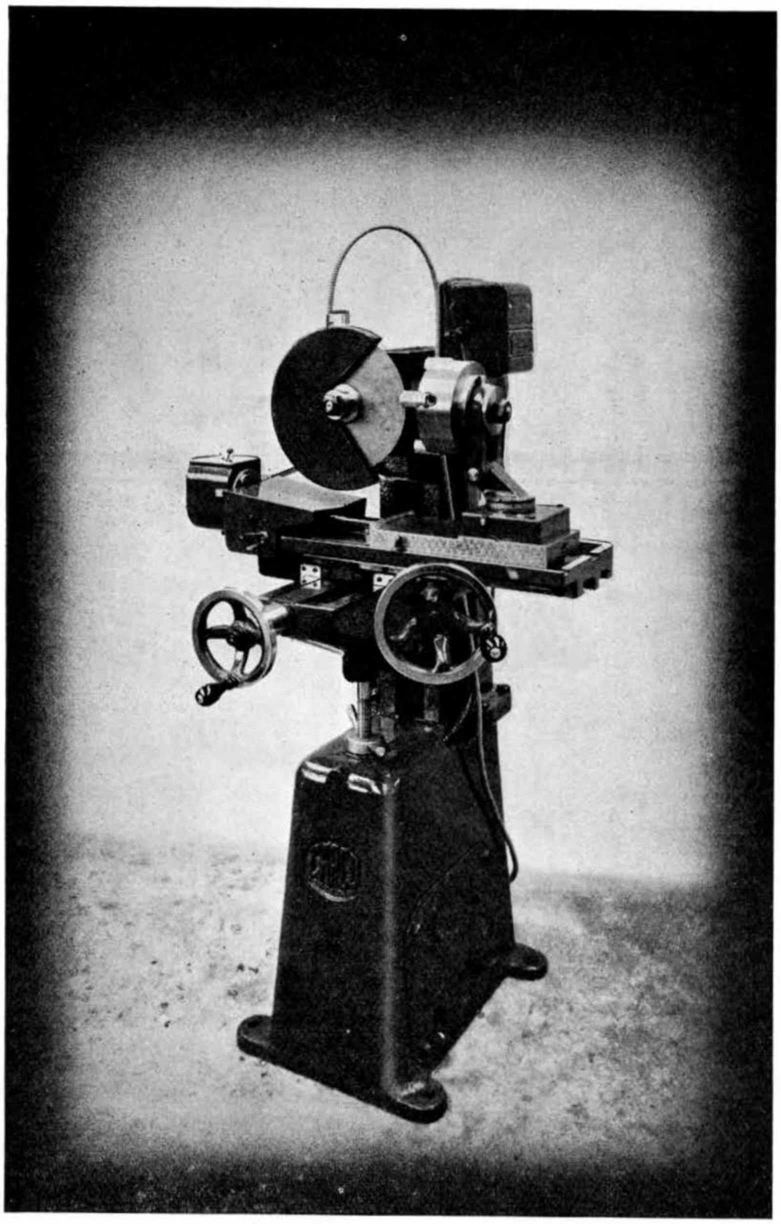

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THE POST OFFICE ELECTRICAL ENGINEERS' JOURNAL

Vol. XXXII July, 1939 Part 2

Post Office Cabling in the Mersey Tunnel

D. A. BARRON, M.Sc., A.M.I.E.E.

U.D.C. 621.315.23 621.315.68

The author describes the cabling and jointing work recently concluded in the Mersey Tunnel. This work presented many unusual difficulties due to limited times of access, restricted space, and the cold air current necessary for the ventilation of the tunnel.

Introduction.

EXTENSIVE cabling work is now in hand in connection with the forthcoming conversion of the Liverpool Area to automatic working. The scheme necessitates the provision of a new junction network to serve exchanges in the Wirral peninsula, the junction cables crossing the river Mersey via the new Mersey Tunnel, utilising the facilities provided therein for this purpose and fully described in this JOURNAL in 1934[1]. The land portions of the junction cables are being provided by contract, but it was decided that the Post Office would undertake the cabling and jointing work in the tunnel.

The work comprised the placing in position, jointing, and balancing of five cables over a length of 1.171 miles from the manhole at Shore Road, Birkenhead, through the tunnel, to the cable chamber in the basement of the George's Dock building on the Liverpool side. Fig. 1 shows schematically the layout of the area of operations.

A number of unusual difficulties were encountered, and it is hoped that a description of the work, and of some of the special measures adopted, will prove of general interest.

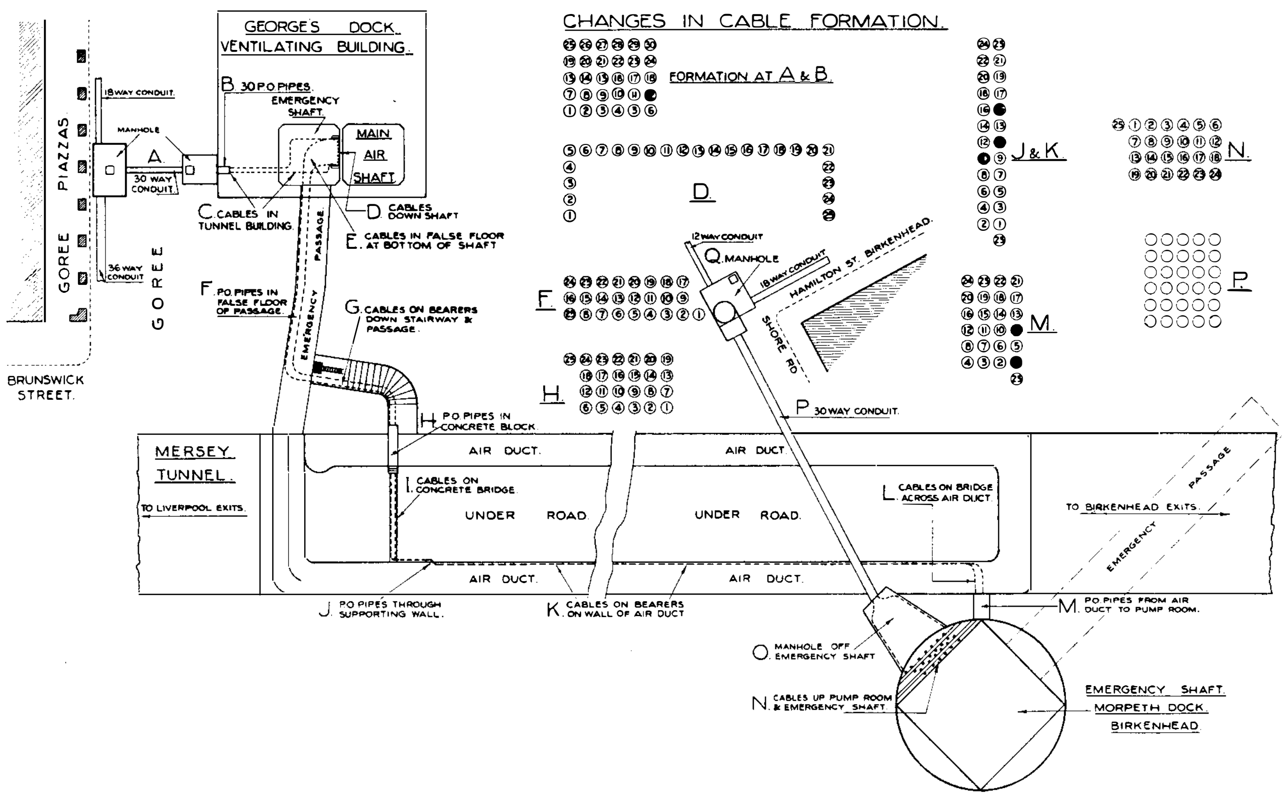


FIG. 1.—LAYOUT OF THE AREA OF OPERATIONS.

General.

The cables to be provided in the cross-river section consisted of four 540/20 pair P.C.Q.L. type, and one P.C.Q.L. 250/20 + 570/10. For the greater part of the distance these cables run in one of the airways, used

[1] *P.O.E.E.J.*, Vol. 27, p. 81.

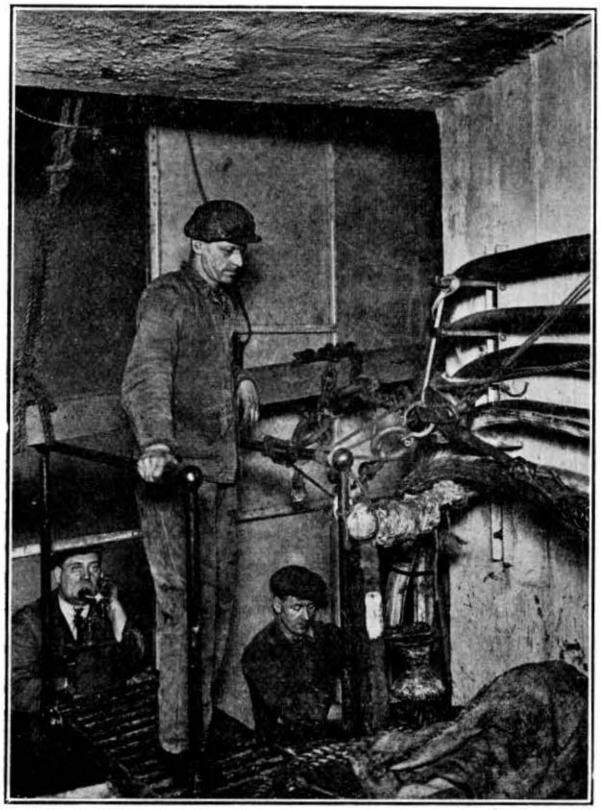


FIG. 2.—POWER APPLICATION POINT AT BIRKENHEAD.

for ventilating purposes, which extend throughout the tunnel underneath, and to the side of, the carriageway. The cables could be introduced to the airway only via manhole covers in the carriageway, necessitating blocking a section of one of the traffic lanes, and the cabling had therefore to be done at night, between the hours of 10.30 p.m. and 7.0 a.m. In view of the size of the cables it was apparent that balancing operations carried out, from the carriageway, between these hours, would be a difficult and costly matter, extending over a long period and necessitating much temporary closing of joints.

It was clear, therefore, when the work was being planned that some means of accommodating the balancing staff and apparatus within the airway would be essential if the work was to be done with the maximum of efficiency and economy. The methods adopted are described in the section of this article referring to balancing and jointing.

Cabling the End Sections.

Cabling of the end sections, both at Birkenhead and Liverpool, presented considerable difficulties on account of thenumber of points where manhandling was necessary in confined space, with the added difficulty of the necessity for absolute co-ordination of effort in moving the cable round a number of bends, through short lengths of pipe, down shafts, over cable bridges, etc., simultaneously in one length. As all the groups of men were out of sight of one another, a system of bell signalling was introduced to synchronise and control their efforts. In addition, the gang foremen at key points maintained constant telephone intercommunication.

At the Birkenhead end, it was possible to employ mechanical power at one point to assist in pulling in, but at the Liverpool end the entire lengths had to be manhandled into position. Fig. 2 shows the arrangement at the power application point at Birkenhead. The rope was fed back from this position for 175 yards through a spare duct, and thence up a 30-ft. shaft to a winch at ground level adjacent to the drum. It will be noticed that a double-eyed grip was used in preference to a split grip. As a minor point of interest, it might be mentioned that it was found that a split grip would hold, in the circumstances obtaining, only with extensive lashing, which was not necessary with the double-eyed grip. As it was necessary to fleet the grip back after every 10 ft. of cable movement the loss of time which would have been involved when lashing and unlashing the split grip—some 16-20 men being meanwhile rendered idle on each occasion—fully justified the wastage, one for each cable, of a double-eyed grip, which on completion of the cabling was cut away and scrapped.

Fig. 3 shows the end of the first section length, the cable at this point entering the airway at the Birkenhead end.

Between the positions indicated in Figs. 2 and 3 respectively, the cable had to pass down a vertical shaft of considerable depth, round the circular wall of the shaft, and thence through ducts to the cable bridge shown in Fig. 3.

The cabling at the Liverpool end, at the George's Dock entrance to the tunnel, proved to be, for the

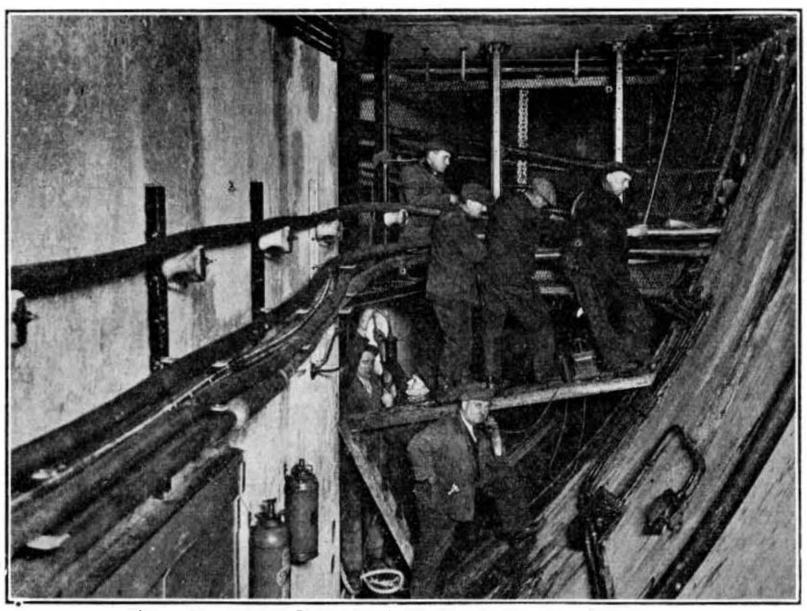


FIG. 3.—FIRST SECTION LENGTH ENTERING AIRWAY.

length of cable involved, viz: 138 yards, the most difficult of all the cabling operations.

The drums were located in the outside roadway at normal ground level. The cable had to pass through the manhole, thence through ducts into the upper cable chamber, down an 80-ft. vertical shaft, thence via an S bend into pipes under a passage-way-floor, down a spiral staircase, across the tunnel under-road, through the side wall, and along the airway wall to its final position. The work was rendered still more difficult by the changes in the formation of the cable necessary at various points in the run, as indicated in Fig. 1. The closest possible control and advance planning of each detail alone enabled the successful accomplishment of this difficult cabling feat. Those who have had experience of manhandling heavy cable in similar conditions will especially appreciate the excellent work of the staff concerned.

Fig. **4** shows the cable being laid across the under-road at George's Dock. It is of interest to compare this with Fig. **14** of the previous article on the Mersey Tunnel already referred to. The thoroughness with which the ultimate Post Office cabling layout was planned during the construction of the tunnel made easier the whole of the work now described, and gave conclusive evidence of the value of long distance planning in such matters.

Cabling in the Airway.

The manholes which provide ingress to the air duct concerned are set in the slow traffic lane. The section of this lane involved was closed by arrangement with the Tunnel Authorities. Lamps and warning notices were provided by the Post Office, and as an additional precaution against accident the Tunnel Authorities supplied three traffic control men to co-operate in directing and controlling the traffic.

It was arranged that cable which had already been manufactured, in 190 yd. lengths, should be utilised. As, however, the carriageway manhole covers were spaced at an average distance of 290 yds. apart, extra difficulties in cabling were introduced.

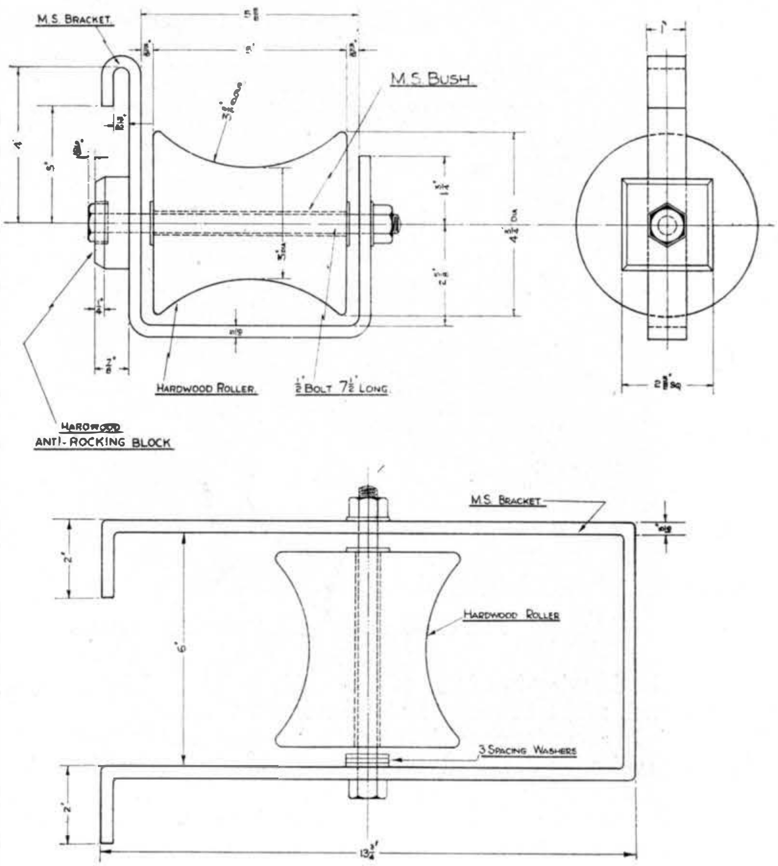


FIG. 5.—TYPE OF CABLE ROLLER EMPLOYED.

The majority of the lengths were required to be so situated on completion that it was often necessary to place the winch as much as 580 yds.—i.e., two manhole sections—away from the drum. In some instances, owing to bends in the tunnel, the winch was out of sight of the cable drum. Further, the trailing end of the cable had sometimes to be drawn considerable distances away from the drawing-in point, and as the free end was, during this operation, in the airway, and therefore out of sight of the men in charge of both the winch and the drum, telephonic communication between all these points had to be arranged.

Experience of the special cabling method adopted, however, indicates that there would be no difficulty in drawing in the full 290 yd. lengths in future works, with resultant economies.

As five cables had to be drawn over the whole length of the tunnel, it was decided to draw in the five corresponding lengths in each section on the same night, if possible, thus finishing the night work in two weeks. This was successfully accomplished, and involved

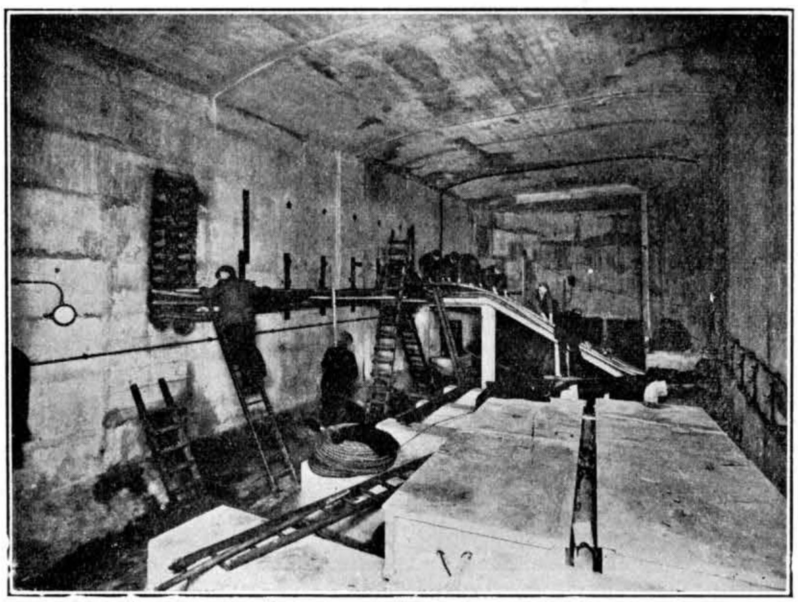


FIG. 4.—CABLING ACROSS THE UNDER-ROAD AT GEORGE'S DOCK.

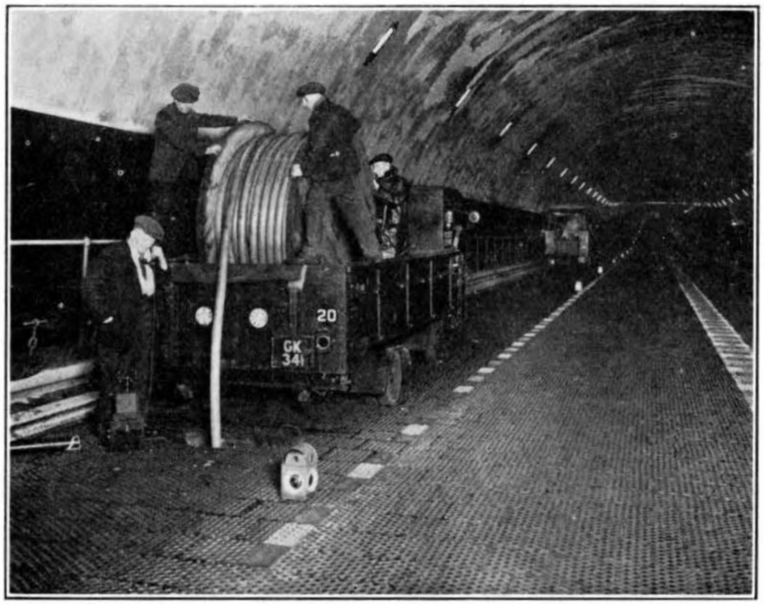


Fig. 6.—Cabling from Tunnel Roadway.

placed on the rollers, each being made off beforehand on to a 3-in. swivel. The ropes had to be used over a maximum length of 600 yards and three standard lengths of 120 fathoms, each of manilla rope, were spliced and used for drawing in each length of cable. The weight of rope employed and its shifting in a confined space presented a very awkward problem and took a considerable time.

This length of rope was necessary owing to the fact that, as has already been stated, the cable lengths were, on an average, 100 yds. less than the manhole cover spacings, so that there were cumulative overlaps, necessitating, on some occasions, drawing past a manhole position.

Portable platforms, 9 ft. by 4 ft. 6 in., standing 6 ft. from the floor, were designed and built locally, and were erected under both manhole covers concerned in the night's operations. These same platforms, which could be converted into raised cabins, by the addition of sides and top, were later used for balancing and jointing operations.

Everything possible was done during the day to assist the night operations, so that the rigid and high-speed timetable for the night-work could be adhered to. The day gangs laid out all ropes, moved platforms and ropes forward for the next night's work, fitted the brackets for the two lowest cables and laid out in the drawing-in of 950 yds. of cable weighing 15 tons, each night between 10.30 p.m. and 7 a.m.

In accordance with the cable bearing arrangements previously designed and provided, the cables had eventually to rest on brackets, two cables on each bracket, at a height varying from 7 ft. 6 in. to 9 ft. from the floor of the airway, the floor being only about 18 in. wide. It was considered that to attempt to draw the cables in along the floor, and subsequently to endeavour to lift them into position, would, in view of the weight of the cables, the restricted space, and the height of the brackets, be an extremely difficult and uneconomical procedure, even if it proved practicable at all. A method was therefore adopted which, by the use of a special type of roller, enabled the cables to be drawn in slightly above the required final position, so that they had only to be dropped a short distance, in a vertical plane, rather than lifted 8 or 9 ft.

The type of roller employed, which was designed locally, is indicated in Fig. 5. The brackets carrying the rollers were designed to fit in the cable bearers in a manner similar to the standard cable bracket, and were fitted into the bearers above the three brackets which were to carry the five cables to be drawn in. 200 of the rollers were made, and were normally used at 7 ft. 6 in. spacing. Vertically mounted rollers were used in conjunction with the horizontal type when it was necessary to negotiate bends. It is interesting to note, however, that it was found in practice that the cable itself would follow the horizontal rollers quite smoothly round bends without the assistance of the vertical rollers, although the latter were found to be essential to keep the drawing-in ropes in position.

To enable the night work to proceed with the maximum expedition, five draw ropes were provided, i.e., one for each cable to be drawn in during that night. Four of the five ropes were laid parallel on the topmost bracket above the rollers, while one was

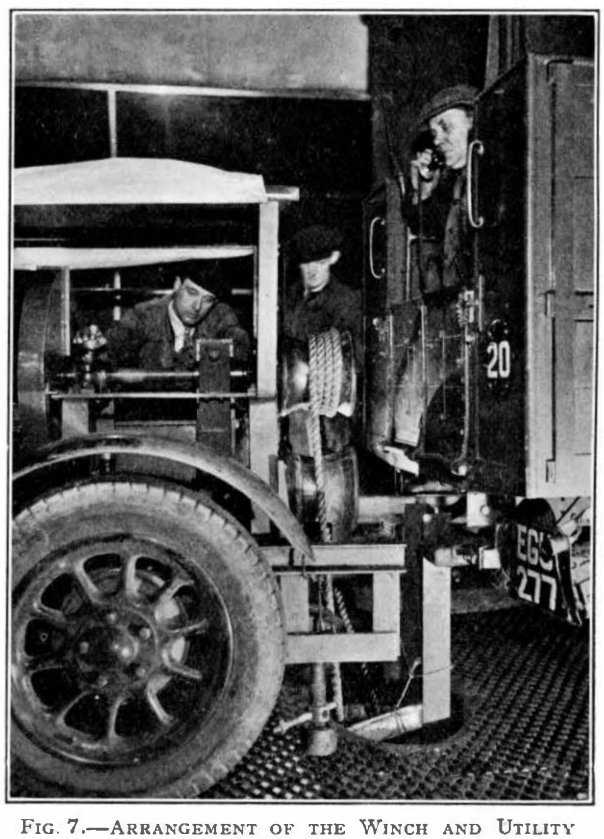


Fig. 7.—Arrangement of the Winch and Utility Vehicle.

position the brackets for the higher cables, fitted the rollers, unbattened the drums and deposited them at the tunnel entrance, dressed down the cable ends and fitted the grips and even filled 50 road caution lamps and trimmed the wicks, thus leaving everything in readiness for the night staff.

Fig. **6** shows cabling in progress. The cable was fed directly on to the rollers via a flexible cable guide. At the winch end, to obtain a straight pull on the rope traversing the rollers in the airway, a 10-in. channel iron was cut to take two rollers at its lower end. The channel was dropped through the manhole to a position where the rollers were in the same horizontal plane as the bracket rollers previously referred to, the upper end of the channel being bolted to the rear of a utility vehicle (in place of the towing hitch) in the carriageway above. The channel was then suitably wedged in the roadway opening, as shown in Fig. **7**.

The ease with which the cables traversed the rollers was remarkable, it being estimated that not more than about quarter of the normal rope tension was necessary. The actual speed of drawing-in was 30 yds. per minute. As soon as the cable had run clear of the drum, and the end appeared through the cable guide, the winch was stopped, and a 10-ft. length of asbestos cement duct slipped over the cable end, and temporarily secured to it. Drawing-in then recommenced, the asbestos-cement duct serving to prevent the trailing end of the cable falling between consecutive rollers during the remainder of the drawing-in operations, the rollers being at 7 ft. 6 in. spacing. The leading end of the cable was watched by a man equipped with a special cable lifter, to obviate any possibility of the leading end running off the rollers and becoming damaged. A typical view of the cable running on the rollers is shown in Fig. **8**.

The cable having thus been placed in its correct lateral position, it was a comparatively simple matter to drop it into its final position on the brackets below the rollers. This was accomplished by a small group of men, using cable lifters designed and made locally, the whole operation of dropping a 190-yd. length of cable into its final position taking not more than 10-15 minutes. This rather interesting feature of the work is shown in Fig. **9**. On their return journey, these men lifted down on to the rollers the next rope, to be seen in position on the top bracket, and when necessary fitted the brackets for the next cable.

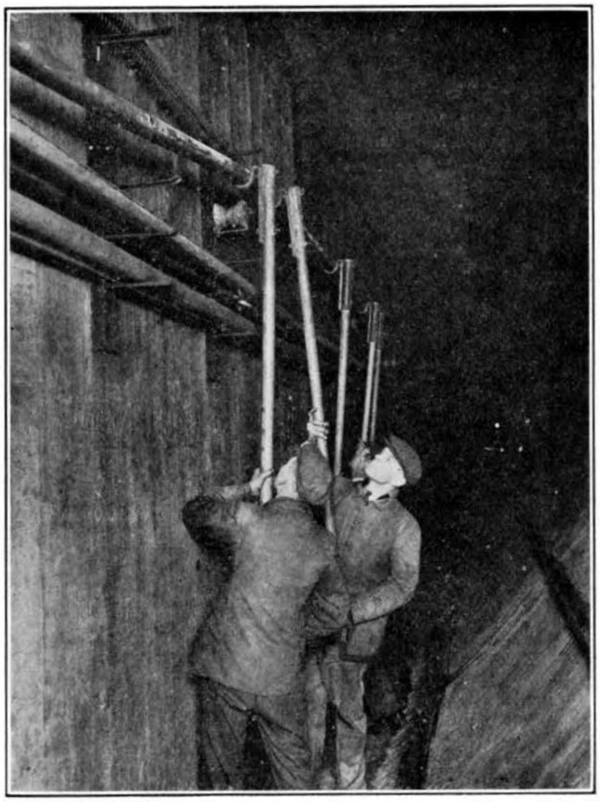


Fig. 9.—Lowering Cable to Final Position.

The whole sequence of operations was then immediately repeated, the next cable drum having meanwhile been set up in position.

Jointing and Balancing.

The interior of parts of the airway is damp, but the most unpleasant feature from the Post Office point of view was the presence of a steady current of cold air, at some 6 m.p.h. or more. The fact that the weather was very cold intensified the discomfort. This air current was, of course, essential for the proper ventilation of the tunnel, and could not be stopped. It was clear, however, that the conditions were such that the staff could only be expected to work in them for comparatively short periods, unless some special measures were adopted. It was decided, therefore, to construct several cabins, to be erected on the

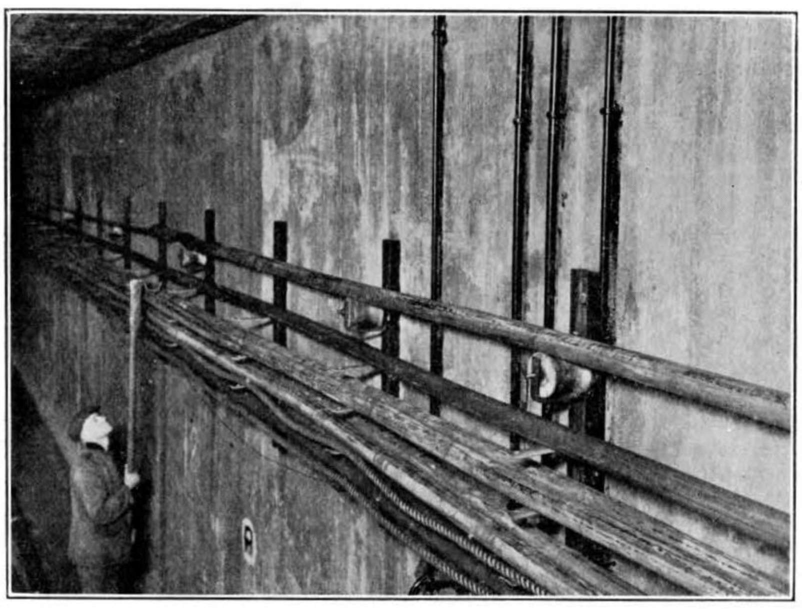


Fig. 8.—Cable Running on Rollers.

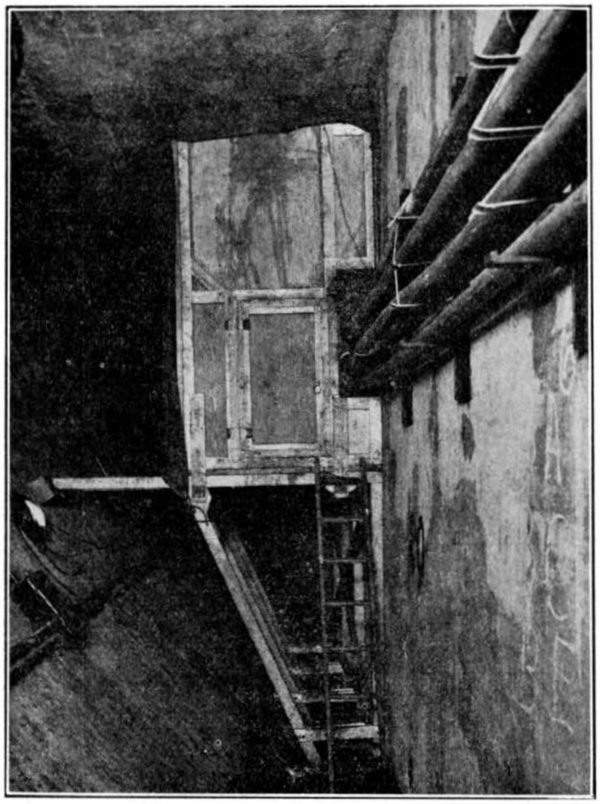


FIG. 10.—JOINTING CABIN.

stands already referred to, to provide snug enclosures for the men, in which good working conditions would exist. Fig. **10** shows an exterior view of one of the cabins. By the use of these, normal shift duties could be worked, and good performance ratings could reasonably be expected. The staff responded excellently, and the rigid programme which had been planned was adhered to without difficulty. The cost of construction of the cabins was doubly repaid because it was possible also to carry out all the balancing work from within them. This not only avoided all the charges for tunnel traffic control officers, etc., which would have been necessary if the balancing had been done from the tunnel carriageway level, but also enabled day work to be performed, and avoided the constant temporary closing of joints which would have been necessary if the balancing had had to be carried out during the short night period only.

The Tunnel Authorities required, however, that blow lamps should not be used except at night, when all the plumbing had consequently to be done. In order to maintain the insulation of the joints, therefore while jointing was in progress during the day-time, when blow-lamps could not be used, electric hair dryers were purchased, and utilised, as an experiment, to play a continuous stream of hot air on the joints. The experiment with the hair dryers was highly successful, and satisfactory insulation figures were obtained throughout.

The cabling had been arranged so that, although the joints on adjacent bearers were staggered, all the joints at one point came within the length of the jointing cabin. This arrangement enabled work to proceed on two joints concurrently at each point. Fig. **11** shows a general view of jointing in progress.

The closest co-operation was necessary, between the jointing and balancing groups, in order that the carefully programmed movement of the cabins from point to point should be closely adhered to. This was successfully accomplished, and the work completed without a hitch.

Very considerable savings were obtained on the estimated cost of the work, which are attributable to the careful and detailed planning of the whole of the operations, the very low cabling costs due to the use of the rollers, and to the energy and enthusiasm displayed by the whole of the staff. The complete success which attended the work is no small measure of the adaptability, initiative, and resource of the Post Office supervising staff, foremen and workmen engaged thereon.

FIG. 11.—JOINTING WORK IN PROGRESS.

Tribute must also be paid to the excellent co-operation afforded by the Tunnel Authorities, and in particular the Traffic Manager, the Electrical Engineer, and the Maintenance Engineer. The assistance given by them was unstinted, and the facilities they so willingly placed at the disposal of the Post Office were of great assistance in achieving economical and expeditious completion of the work.

The Submarine Cable to Pangkor, Malaya

H. E. CORNISH,
B.Sc., A.C.G.I., A.M.I.E.E.
(F.M.S. P. & T. Dept.)

U.D.C. 621.315.285

The author describes the arrangements made to lay a submarine cable from the mainland of Malaya to an island about two miles distant. The work was undertaken by personnel inexperienced in this type of work and without any special equipment. The manner in which the difficulties were overcome is described and improvements suggested.

General.

THE island of Pangkor lies about two miles off the west coast of Malaya, some eighty miles south of Penang. It is the centre of a flourishing fishing industry and has its own works for production of ice in which to pack fish prior to distribution. It is also a fairly popular holiday resort, on account of the natural beauty of the scenery and pleasant sandy beaches for bathing. A number of bungalows are in existence for holiday use.

There are no telephones on the island and it has been decided that if telephones were provided, development, both commercially and as a holiday resort, would be accelerated. Subscribers initially to be connected would number about seven, and service would be provided by an exchange of the R.S.A.X. type on the island, linked to the nearest group centre exchange, Sitiawan, on the mainland.

Specification.

The shortest distance between the island and the mainland is two sea miles, and the specification of the cable for provision of the junction is briefly as follows :—

The length is 3,650 yards, manufactured in one length free from joints, consisting of four twisted pairs, each conductor being of 7/·029 in. tinned copper, insulated with new C.M.A. standard rubber.

The conductors of each pair are twisted together and sheathed in a tough rubber compound, taped and covered by brass tape.

The four pairs are twisted together with a uniform lay wormed circular with compounded jute and then served with sufficient compounded jute to form a bedding for the armouring.

The armouring consists of two layers of " Homo " iron wire with a layer of compounded jute separating the layers.

Over the armouring is a further layer of compounded jute, which was whitewashed. The weight of the cable is about 32 tons and its overall diameter about 3 ins.

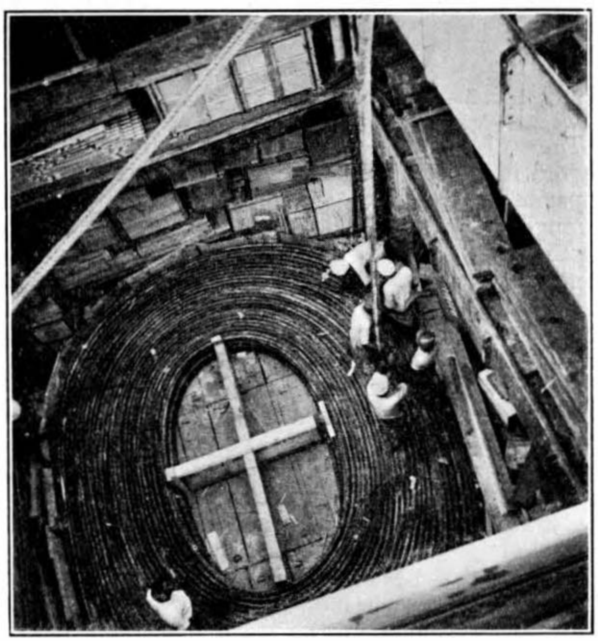


FIG. 1.—CABLE BEING UNLOADED FROM SHIP'S HOLD.

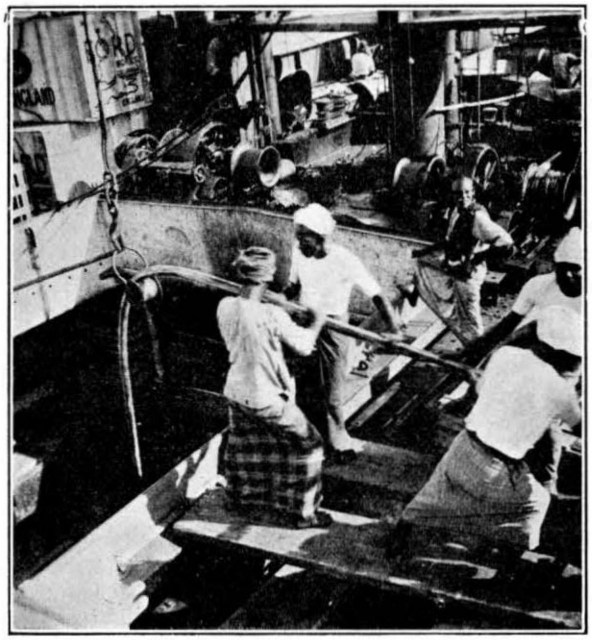


FIG. 2.—CABLE PASSING OUT OF HOLD.

Unloading.

The interest in the handling of the cable lies chiefly in the fact that it was done by personnel inexperienced in this type of work, and with makeshift arrangements. This note therefore describes the methods used, and suggests improvements.

The cable arrived by ship at Penang, stowed in the hold at sea level. It was coiled on the floor of the hold enclosed in a skeleton crate. The cable was pulled vertically from the hold, passed over a roller, horizontally across the deck and thence over a second roller into a lighter alongside the ship. The weights of the two vertical parts balanced each other approximately.

A gang of men stationed on the deck of the ship passed the cable into the lighter. The operation is photographed in Figs. 1, 2 and 3. The unloading was completed in six hours, and was hard work for the men stowing the cable in the lighter, because the cable was fed in jerks by the deck gang and it did not descend vertically into the lighter. Some form

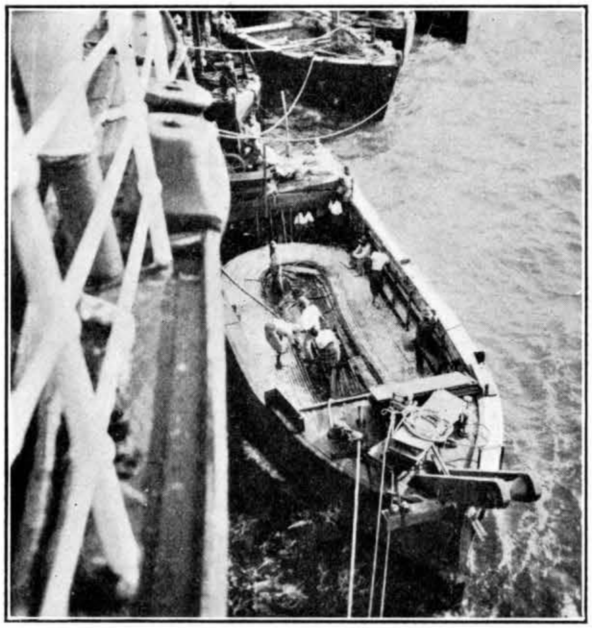


FIG. 3.—SHOWING THE CABLE IN THE LIGHTER.

of steady drive should have been provided in a form similar to a mangle through the rollers of which the cable would pass. A guide ring fixed to the ship's side vertically above the centre of the lighter would have eliminated some heavy handling work in the lighter.

In stowing the cable every precaution was taken to ensure that it would pay out easily during the final laying, since it was realised that in the event of difficulty, stoppage could not be effected before damage might be done.

The dimensions of the lighter were 30 ft. by 12 ft. and the inner turns of the coil were of fairly small radius so that the cable might be expected to spring

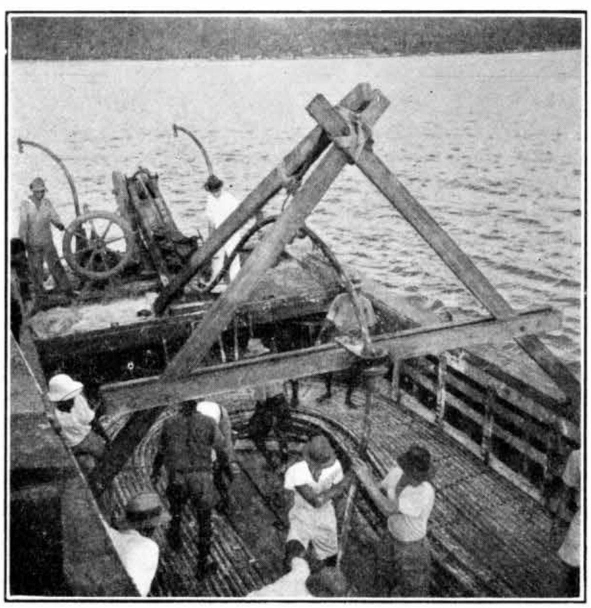


FIG. 4.—LAYING THE CABLE FROM THE LIGHTER.

unless restrained. Coiling was therefore done from outside to inside in each layer so that the inner turns would always be held by the outer. The cable at the cross-over from inside to outside between each layer was protected by timber of wedge-shaped cross-section laid alongside it.

To prevent sticking, whitewash was lavishly applied to each layer, and slats of wood were laid radially at 2 ft. intervals between layers.

Laying.

The loaded lighter was towed to Pangkor where it was prepared for laying. A tripod of 6 in. by 3 in timber was erected above the cable, as shown in Fig. **4**, in which will be seen the horizontal bar carrying a central guide ring. The cable was passed through this, over a roller, Fig. **5**, then to a cable-brake, Figs. **6** and **7**, and finally over the stern into the sea.

FIG. 5.—VIEW OF THE GUIDE RING AND PULLEY.

The cable-brake was composed of three fixed curved iron jaws, with two movable jaws staggered opposite to them. The action was similar to a vice, through which the cable was drawn. A study of the depth chart of the channel showed a maximum depth of about 12 fathoms, where the dead weight of the cable over the stern was estimated to be about 1,000 lbs. The object of the brake was to prevent the cable running away on its own due to the dead weight and at the same time it was hoped that some control of speed of laying could be effected by it. In the latter we were disappointed, as it was found that, with the jaws screwed home as far as was judged to be safe without distorting the cable to the extent of causing damage, very little positive control of speed could be obtained.

The lighter was placed as near the shore as possible, and the end drawn ashore by ropes. It was buried in a zig-zag trench to provide a firm hold against subsequent pulling. The lighter was then towed slowly to a point from which the laying proper was to commence on the following day.

During this short slow tow the action of the cable while paying out was carefully watched and it was seen that considerable twisting occurred with a definite tendency to form a small loop as it left the coil near the centre of the lighter. It was therefore decided that continuous manual restraint would have to be applied to prevent such a dangerous occurrence.

This demanded the slowest possible rate of laying, and it was arranged that the towing should be done by a diesel launch ahead with a steam launch rigidly lashed alongside the lighter. The steamer could thus be quickly reversed, providing means of stopping the lighter as rapidly as possible.

The following morning, just before high tide, laying commenced, but it was quickly found that with these towing arrangements it was impossible at slow

FIG. 6.—VIEW OF CABLE BRAKE AND STERN OF LIGHTER.

speed to keep on the course indicated by two white marking posts aligned on the mainland shore. There was a wind and a slight current, and the difficulty was to get the diesel launch to pull in the direction necessary to compensate for the effects set up by them. There was insufficient speed for effective steering either by the diesel or the steam launch.

The shelter of the land had been left by this time, drifting had commenced and a rapid change of plan was necessary ; most worrying in a work of this sort.

The diesel launch was dispensed with and engine speed on the steamer increased until steering way was just obtained. The cable was then paying out uncomfortably fast for the necessary manual restraint. However, the course was kept, and laying successfully completed in little over one hour from the start. The hands of the staff were severely chafed.

The lesson learnt was that the central guide ring in the lighter should have been at least twice as high,

FIG. 7.—CABLE BRAKE IN OPERATION.

say 12 feet above the cable, so that the slack would have been sufficient to take up the momentary twist without kinking. It is believed that handling would then have been unnecessary, and the cable could have been laid comfortably at a good steering speed for the towing craft.

At the finish of open-sea work there remained in the lighter about three-quarters of a layer of cable with its end outside, and paying out had to be effected from the inside. The cable was freed from guide ring and brake and rearranged so that it was laid over the bow instead of the stern, passing under the lighter. The upper part of the loop thus formed was drawn out in small bights by hand, as shown in Fig. 8.

FIG. 8.—LANDING THE SHORE-END.

The Production of Quartz Resonators for the London-Birmingham Coaxial Cable System

C. F. BOOTH, A.M.I.E.E., and C. F. SAYERS

U.D.C. 549.514.1 621.315.212 621.396.662.3

The final section of this article deals with the production of the Quartz Resonator using the processes described in the previous sections, after which the electrodes are plated on the crystal by a sputtering process and the final tests and adjustments made.

Cutting.

A SELECTED crystal is set up in a cement chuck so that the principal axis is approximately perpendicular to the chuck base, a small piece of clay or plasticene being set under the crystal as a means of support. The crystal and chuck are then placed in a special angle gauge as shown in Fig. 29 and adjusted until Z axis is perpendicular to

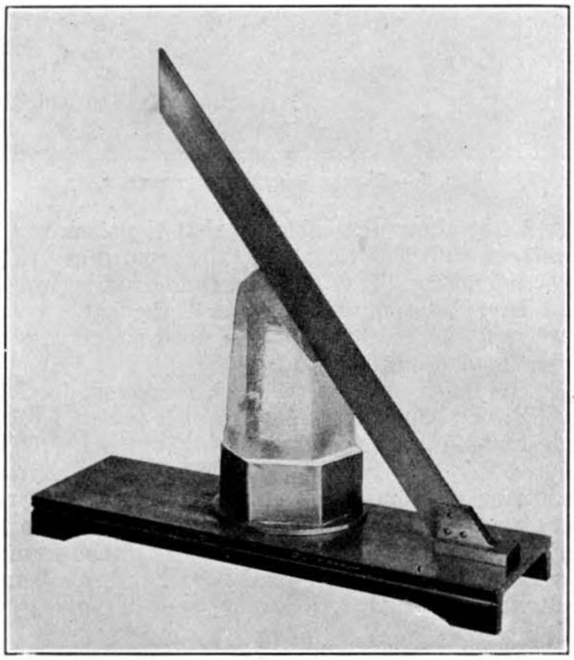


FIG. 29.—MOUNTED CRYSTAL IN ANGLE GAUGE.

the chuck base. The accuracy of the adjustment is determined by the condition of the pyramid faces; with two or more good faces the error has been found to be within 0° 30′. In the absence of good pyramid faces the growth lines on the m faces may be used if they are sufficiently well developed and they should be made parallel to the chuck base, but the degree of accuracy is not equal to that which is attained when the pyramid faces are employed. When the adjustments are completed the crystal is firmly cemented in the chuck with plaster of paris; a number of crystals so mounted are shown in Fig. 30. The crystal is marked off for cutting into slabs of thickness equal to the specified z dimension of the finished plate plus a lapping allowance of 1 to 2 mm. The crystal is then cut into slabs using the cutting machine described earlier. A number of cut crystals is illustrated by Fig. 31.

The cut slabs are first examined in the workshop polariscope to ascertain the presence and position of optical and/or combined optical and electrical twinning, and slabs which pass the preliminary

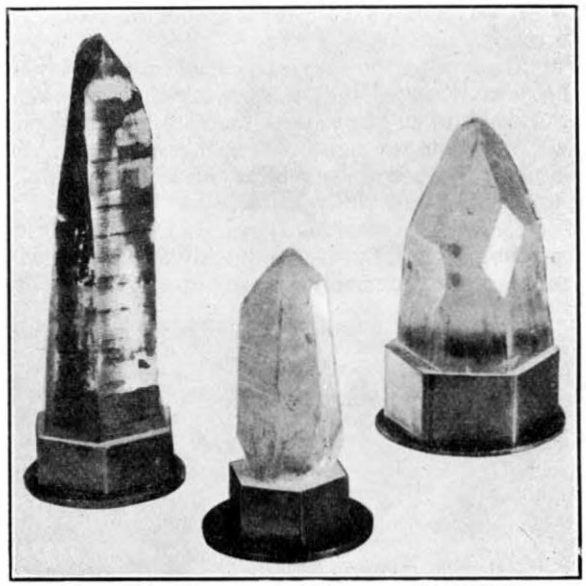


FIG. 30.—GROUP OF MOUNTED CRYSTALS.

optical examination are further tested for the presence of electrical twinning by etching. If the slab is found to be satisfactory in quality, it is trued to the Z axis with the aid of the optical system which has been described. The finished slab is then mounted on a glass disc with ceresine wax ready for loading into the fixture, which is used on the cutting machine.

The mounted Z slab is next set up in the fixture and two Y cuts are made with sufficient spacing to obtain

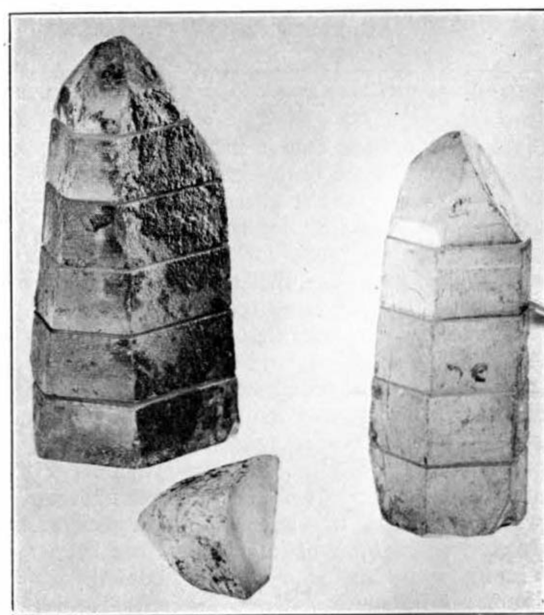


FIG. 31.—GROUP OF CRYSTALS CUT INTO Z SLABS.

a slice of the required y dimension plus a lapping allowance of 1 to 2 mm. The block is then removed from the glass disc and the Y cuts are lapped smooth and flat and are trued to the Z plane. The slab is remounted with glass strips on each trued Y face and on the top surface; the purpose of the strips is to steady the saw at the commencement of the cut and to hold the slice while the saw is passing into the glass. When replaced on the machine the Y surfaces are set parallel to the saw spindle axis; the X axis is thus brought perpendicular to the plane of the saw. The block is then sliced, each slice being perpendicular to the X axis. The thickness of the slice is approximately equal to the specified value plus an allowance of 0·1 to 0·2 mm. which is made on each side of the slice for lapping and which ensures the complete removal of the slight taper in the cuts and all traces of the saw marks. The automatic stop is set to control the depth of cut, the thickness of the slice being controlled by the amount of rotation of the transverse feed screw which is read off on the micrometer collar.

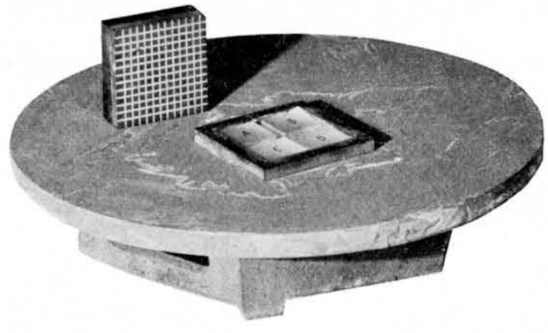
It should be appreciated that this system of cutting is rendered possible only by the application of a machine capable of accurate cutting and precise adjustment. The method which has been employed in the past and which is used by some organisations at present is one in which the slab is trued in the manner which has been described, a slice is then cut from the slab and the cut face of the slab is retrued before the next cut is made, the process being repeated until the slab is completely sliced. The method is expensive and laborious and was necessary because of the lack of accuracy of the old type cutting machine.

The slices are cleaned in a bath of commercial xylol to free them from all traces of cutting lubricant and wax and are examined for the presence of small cracks and inclusions, and, in addition, a final etching test for electrical twinning is made. This test is necessary because there may have been twinning inside the slab which was not revealed on the surface by the etching test carried out on the slab. About ten minutes' immersion in HF acid is sufficient to show electrical twinning in a cut slice if it is dipped in water before it is examined by transmitted light.

Lapping.

The first part of the lapping process is one in which the x dimension, the thickness, is adjusted to the specified value, both major surfaces of the slice being operated on in order to correct the taper which occurs in the cutting process and so to retain the accuracy of these surfaces in relation to the crystallographic axes. For this purpose the plates are reduced to the final thickness by lapping them in sets of four.

The slices are placed in a square frame (Fig. **32**) in which they are just free to move and are lightly pressed upon the lap by a pad fitting loosely into the frame. The under surface of the pad is flat and ventilated, i.e. grooved at intervals, to prevent the slices sticking to, and being lifted up with the pad. After a short period of lapping all the plates are turned over and a diagonal pair is interchanged; this operation is repeated at regular intervals, a different pair being changed each time, until the required size is obtained. The interchange, provided it is done frequently, produces and maintains uniformity in thickness and corrects the inaccuracy of the surfaces due to the taper. The pad and frame are of ebonite, and the frame is grooved in its under surface to allow the grinding powder to flow through to the slices. During the lapping process the thickness is measured at intervals with the aid of a standard micrometer (mm. scale) and no difficulty is experienced in adjusting x to within $\pm$ 0·0025 mm. of the specified value.



(a)

(b)

FIG. **32**.—LAPPING PLATES BY INTERCHANGE METHOD.

When a set of plates is adjusted for thickness the other two dimensions are operated on, and this is known as the "edging" process. It is performed by lapping, or by cutting and lapping if the plates are considerably over size. In practice, the whole set of plates is operated upon simultaneously by waxing them together to form a solid block. As many as 64 plates have been worked in this way, but the number is limited by the strength of the wax. A block of 53 finished resonator plates is shown in Fig. **33**. Each plate is arranged in the block so that the corresponding true face of each forms part of one block face from which the other three faces are worked. In this way the contour of the finished plate is accurately aligned to the crystal structure. A block so formed can be very accurately worked to predetermined dimensions and squareness of the edges is easily maintained.

The process of making up a block is perhaps of some interest. First, a number of lapped slices are care-

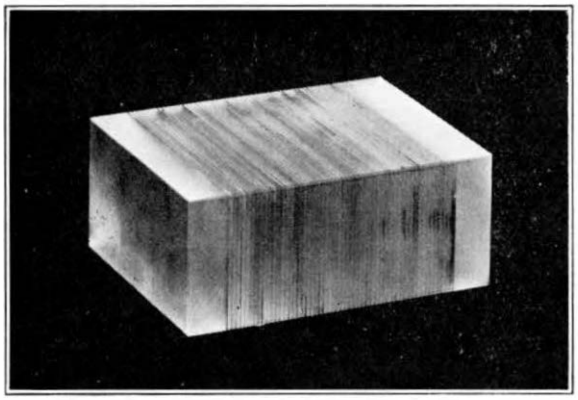


FIG. 33.—FINISHED BLOCK OF 53 PLATES.

fully cleaned and arranged in a pack with corresponding trued faces together, a thick glass plate of suitable size being placed at each end of the block to give protection to the end slices during lapping. The pack is then held together by a light clamp and heated in a shallow tray of ceresine wax until the molten wax has been drawn up between the plates by capillary attraction, care being taken to allow the film of air between the plates to escape from the top surface. The pack is next transferred to the special clamp, illustrated in Fig. 34, and placed with the true

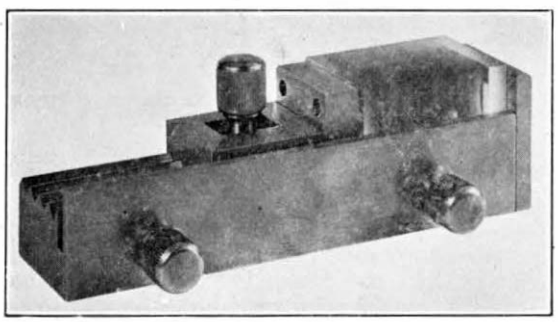


FIG. 34.—BLOCK OF PLATES ASSEMBLED IN CLAMPING DEVICE.

faces resting on the ribbed base. This clamp enables the plates to be aligned vertically and horizontally, and to be made perpendicular to the common axis of the block.

The reduction of the block to the final dimensions by roughing down on a rotary lap and finishing on a hand lap is controlled by micrometer measurement and by a vertical dial gauge comparator. The comparator is used to indicate the z and y dimensions of the block, and to show when parallelism of the opposite faces is obtained. A block of resonators in the comparator is shown in Fig. 35. The dimensions of a block are finally checked in a small precision measuring machine of a range up to 7·5 cm. and measurement accuracy better than $\pm 0{\cdot}001$ mm.

When a finished block has been checked for size it is examined in the polariscope, Z axis of slab parallel to instrument axis, as a final check for optical twinning. Finally the plates are separated by heating the block; they are carefully cleaned and are then ready for the electrode plating and final adjustment processes.

In lapping the y dimension of the block it is, of course, necessary to adjust y to the specified value plus the minimum allowance which will ensure that all the plates in the block give a slightly lower value of series resonant frequency, f_r, than is specified. For economic reasons the allowance must be as small as possible, as after the plates have been separated from the block each one must be given individual treatment which is much more expensive than the bulk method already described. In this connection it will be realised that lack of accuracy of the plates with regard to the crystallographic axes, to geometric form and to dimensions is reflected in the frequency

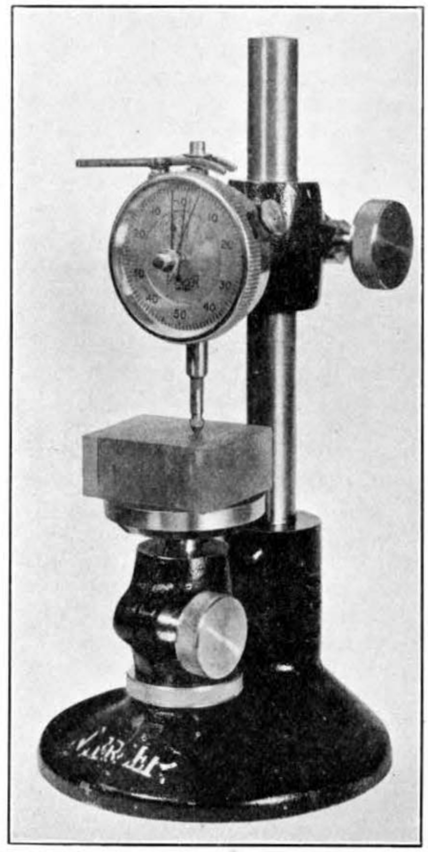


FIG. 35.—BLOCK OF PLATES IN VERTICAL COMPARATOR.

constant and therefore in f_r. Thus the value of the allowance is a criterion of the methods, the smaller it can be made without causing plates to be rejected due to f_r being above the specified value the more successful the process. With the system which has been described it has been found practicable to reduce the allowance to a value which gives an average f_r for a set of some 50 plates only 100 c/s less than is specified, the corresponding frequency limits on the set being $f_r - 25$ c/s and $f_r - 175$ c/s.

Final Adjustment and Test.

Before the actual method of final frequency adjustment is considered it is proposed to describe briefly the principle of the test equipment.

The primary considerations in the process are the adjustment and measurement of the resonant frequencies of the series circuit LRC, f_r, and of the parallel circuit $LRCC_1$, f_a, of the equivalent circuit (Fig. **36**) and of the decrement of the series circuit. In

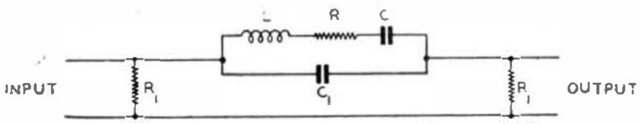


FIG. **36**.—EQUIVALENT CIRCUIT OF COUPLING ELEMENT.

consequence, the test equipment differs appreciably from that employed for oscillator plates.

The resonator functions as the coupling element between an oscillator and amplifier (Fig. **37**), and

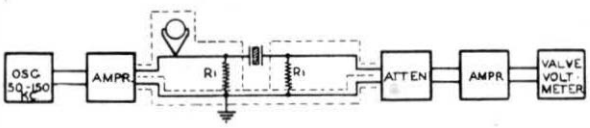


FIG. **37**.—BLOCK SCHEMATIC OF RESONATOR TEST SET.

with the aid of a calibrated attenuator and a voltmeter, both of which are incorporated in the amplifier, the response curve of the coupling element is obtained. The curve of attenuation for constant output (Fig. **38**)

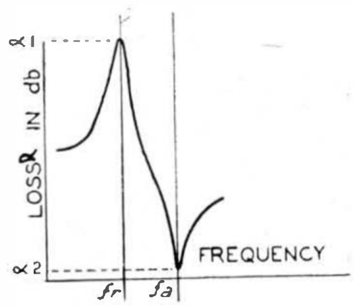


FIG. **38**.—FREQUENCY-LOSS CHARACTERISTIC OF CRYSTAL FOR CONSTANT OUTPUT.

gives a measure of the resonant frequencies of the series and parallel circuits and of the dissipation of the equivalent circuit. At frequencies much lower than f_r the attenuation for reference output is, say, a db., as the oscillator frequency approaches f_r the effective impedance of the crystal resonator decreases and, at resonance, is given by R shunted by C_1, and it is necessary to increase the attenuation to a_1 for reference output. The frequency, f_r, is given by $\omega_r^2 = \frac{1}{LC}$. At a higher frequency, f_a, where $\omega_a^2 = \frac{C + C_1}{LCC_1}$, the effective inductance of the series arm becomes equal in magnitude to the capacitative reactance of C_1 and the impedance becomes $\frac{LC}{C_1 R (C + C_1)}$, the coupling is thus decreased and the attenuation must be reduced to a_2 db. to obtain reference output. The reactance curve of the equivalent circuit is given in Fig. **39**. The decrement of the circuit is given to a first approximation by

$$\left(\frac{f_a}{f_r} - \frac{f_r}{f_a}\right)\frac{\pi}{\sqrt{x}}$$

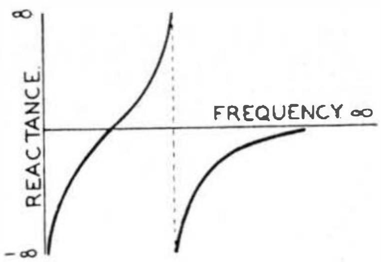


FIG. **39**.—REACTANCE CURVE OF CRYSTAL.

where x is the ratio of the voltage across the input of the amplifier at the frequencies f_r and f_a. The ratio C_1/C is given by $\frac{f_r^2}{f_a^2 - f_r^2}$.

It is essential that C_1 is not augmented by stray capacitances otherwise the computed values of decrement and the ratio C_1/C are erroneous. For this reason the resonator electrode connections are earthed in proximity to the resonator through low value resistors, all the leads are effectively screened and their capacitances to earth are made as low as practicable.

A photograph of the complete equipment is given in Fig. **40**. The oscillator is of somewhat special

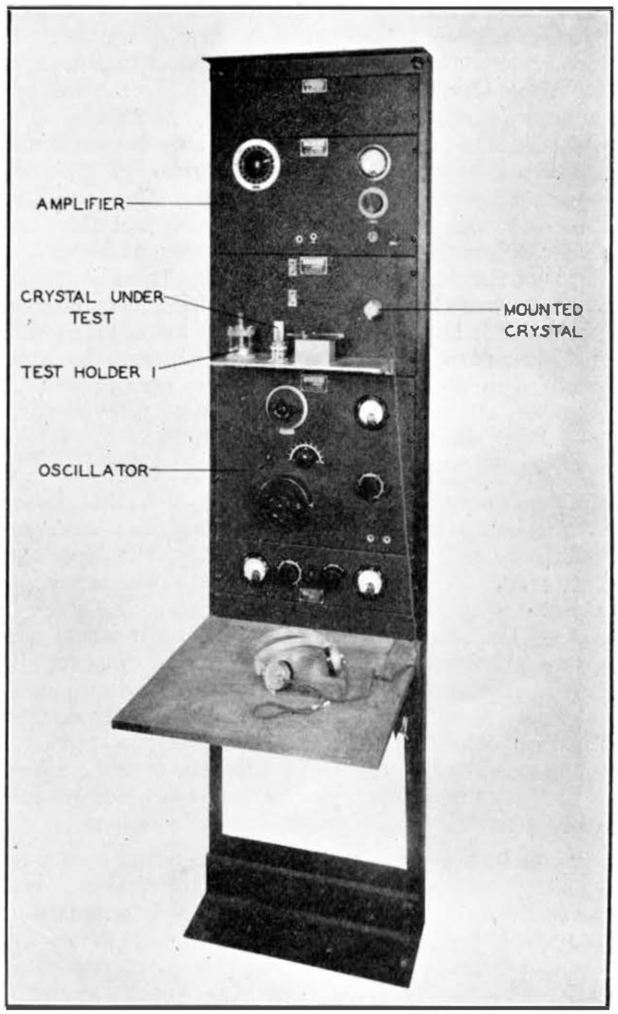


FIG. **40**.—RESONATOR TEST SET.

design to enable f_r to be determined within $\pm$ 2 c/s; it is not possible to measure f_a to a similar accuracy because of the lack of sharpness of the response in that region. A frequency checking unit which provides a harmonic series from the Post Office frequency standard, 1 kc/s, is incorporated to allow of the oscillator calibration being checked as and when necessary. The remainder of the equipment is a more or less standard design with the exception of the holder panel which is designed to facilitate the testing of resonators on a mass-production scale. Three plug-in test positions are incorporated; the first is arranged to take an air-gap holder which is used for preliminary measurements; the second accommodates the trolitul disc of the standard holder, and the completely assembled holder may be plugged into the third position.

The operation of the equipment is comparatively simple: first the oscillator calibration and the amplifier gain are checked and adjusted to datum, the crystal is then placed in one of the three test positions—according to the stage of adjustment—and the values of f_r and x are determined. It is not necessary normally to complete the response curve, as the faulty performance of a crystal is clearly reflected in f_r and x.

The actual adjustment of the resonators can be considered in two stages. In the first, the frequency of each resonator in a set is adjusted before it is plated, by lapping the y dimension to give a value for the series resonant frequency of f_r-f_p, as measured in a special holder with a fixed air-gap between the crystal and the top electrode, the crystal being placed in contact with the bottom electrode. The term f_p is a factor which takes into account the fact that the holder differs from the standard holder, and also the fact that the resonator is not plated. The allowances for these two changes are known within very narrow limits and it is possible at this stage to adjust a set of 50 resonators so that when they are plated and mounted in the standard holders the series resonant frequency of each one lies in the range $f_r - 10$ c/s to $f_r - 50$ c/s, where f_r is the specified value.

In the final stage of the process the electrodes are first plated on the resonators as is described later, each resonator is then mounted in its holder, less spun container, and is adjusted to give the specified frequency. For this purpose No. 2 position on the test unit is employed and, as indicated in the description of the standard holder, it is not necessary to remove the resonator from the spring contacts for the final lapping of the y dimension. When the measured frequency is within the specified limits, the mounted crystal is placed in the spun container, the container is sealed and engraved and a final check of f_r, x and of the leakance across the electrodes is made several weeks after the sealing process.

It will be appreciated that the final adjustment and testing is an exceedingly skilled operation; one faulty move on the part of the operator is sufficient to spoil the resonator at the final stage when its value is considerable, and consequently considerable care and a double check at each stage is essential.

Electrode Plating

The need for electrodes contiguous to the surfaces of the resonator crystals has already been discussed. The primary considerations in the specification of the electrodes are that they be non-tarnishing, adhesive, of low resistance and do not seriously load the crystal. This specification is satisfied by the metals platinum and gold, the latter being most suitable because of its higher conductivity, and after due consideration it was decided to carry out preliminary experiments with platinum and gold, using the cathodic sputtering process.

The process is one in which an electrical discharge is maintained between two electrodes in a highly attenuated atmosphere, the cathode being formed of the sputtering material, and the object to be plated being mounted between the electrodes. When the electrical discharge takes place the intervening space becomes conductive and the positive ions are attracted to the cathode. The momentum of these relatively heavy ions is such as to cause the disintegration of the cathode, and some of the particles removed therefrom fall on the crystals which thus receive a metal coating.

Much data was obtained with an experimental plant which enabled the specification of a commercial set-up to be drawn up. Very early it was found that adhesive coatings could be obtained only when the surfaces were perfectly clean. In this connection it is of interest to note that it was possible to solder a wire to a sputtered platinum film. The joint was tested to destruction, and the load carried by the wire before the failure of the joint clearly indicated the grip of the film on the plate surface.

The preliminary tests were carried out with platinum and gold, but after due consideration it was decided to employ gold electrodes. The final equipment is illustrated by Fig. 41. It comprises a vacuum

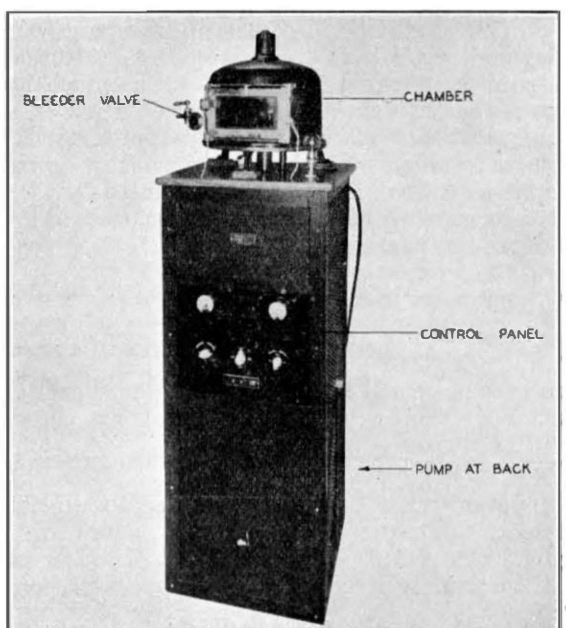


FIG. 41.—SPUTTERING APPARATUS.

pump, vacuum chamber, and a rectifier unit which provides the power for the discharge, and was designed to deal expeditiously with the resonators. A sputtering time of some 20 minutes is necessary to plate each side of the specimen—it is necessary to turn over the specimen to plate both surfaces—and the unit will handle some 150 sq. cm. per charge. Special precautions are necessary to ensure that the edges of the specimens can be easily cleaned of the residual material which accumulates on them during the process. This is accomplished by coating them with a special solution before the sputtering process which enables the gold to be washed off with ease.

Performance of the Resonator Plates

The 1,408 resonators required for the equipment of the first 40 circuits on the London-Birmingham coaxial cable were produced according to schedule, and the methods of production described are considered to have been justified by the performance of the crystal filters.

Complete details of the methods evolved by the Post Office, including the design of the cutting machines, have been given to the Contractors interested in the production of coaxial cable equipment and a specification for resonator plates has been drawn up. A brief outline of the specification is given in the Appendix. The equipping of additional super-groups is now in hand, and the resonators for the terminal equipment are being produced by a Contractor in accordance with this specification.

Many thousands of resonator and oscillator plates have now been made in the Crystal Laboratory, and the work which has been described has proved of considerable assistance in the production of the many types of crystals which have been handled.

Acknowledgments

The completion of the work has been rendered possible only by the co-operation of a loyal staff. It is not possible to particularise, and so the Authors wish to take this opportunity of publicly expressing their thanks to all members of the Crystal Laboratory staff for their efforts and help.

APPENDIX

Specification of Quartz Resonators

Material and Dimensions.

The quartz to be free from optical and electrical twinning and from cracks, flaws, discolorations, rain and bubbles.

The plates to be plane parallel within 0·0025 mm., the x and z dimensions to be within $\pm$ 0·005 mm. and $\pm$ 0·01 mm. respectively of the specified values, and the y dimension to be adjusted to give the quoted Y wave frequency. The finish of the plates to be fine matt as obtained with 600 abrasive, and the edges to be sharply defined and free of fraying and chipping.

Electrodes.

The electrodes to be of gold deposited on the XZ plane surfaces by cathode sputtering, precautions being taken to ensure that no gold is deposited on the other faces during the process. The plate faces to be perfectly clean before the sputtering process and the thickness of the gold film to be such as to give a resistance in the range 4-5 Ω between two contact electrodes spaced $\frac{3}{4}$ of y apart and sufficiently long to cover the z dimension when the applied voltage is 2 V.

As an alternative aluminium electrodes deposited by the evaporation process may be employed.

Mounting.

Each plate to be mounted in a sealed standard resonator holder so that the centres of the lines joining the contact points and the centres of the plate are in line, and the line of contact makes an angle of 19° with the Z axis of the plate, the sense of the angle being such that the contacts are in the nodal plane of the Y vibration. The holder spring tension to be adjusted just to prevent movement of the plate when the holder is subjected to normal jars and vibrations.

The mounted crystal and the inside of the can to be free of grease and moisture and to be perfectly clean immediately before sealing. " Seekay " Wax A70 to be heated just to melting point and the wax to be poured into the top of the can until the trolitul is flooded to a depth flush with the top of the can. The wax to be allowed to cool for one minute and the top of the can to be dipped into the wax bath to 0·5 cm. below the rivet heads, the holder to be quickly removed and allowed to cool.

Performance.

The series resonant frequency of the sealed crystals to be within $\pm$ 10 c/s of the specified values at 20° C. The difference in response between the series and parallel resonant frequencies as measured in the Standard Resonator Test Set to be not less than 65 db. The leakage resistance between electrodes with an applied voltage of 10 V to be greater than 100 megohms. The frequency, response and leakage tests to be made not earlier than one month after the crystals are sealed.

The Application of Hollerith Accounting Machines to the Distribution of Engineering Instructions

U.D.C. 681.177.5 : 621.39 (083.9)

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Insufficiently selective distribution prevented Engineering Instructions from being fully effective and a new method of distribution on a functional basis has been devised. Operation of the scheme depends on the analysis of punched-card records by machines designed for the purpose and developed from standard accounting machines. The application of such machines to an analysis of this type is believed to be novel. This article outlines the scheme and describes the principles of the machines.

Introduction.

PRINTED instructions, as a feature of the Post Office Engineering Department's operations, are about as old as the Department. They have changed in form from time to time but in the last few years have undergone considerable expansion. This has been a natural consequence of the rapid expansion of the Department's activities, the increasing complexity of the work of the staff and the necessity for producing instructions for the large numbers of relatively inexperienced staff which it has been necessary to recruit to cover the increase of work.

To facilitate the indexing and amendment of the Engineering Department's instructions (E.I.s) a loose-leaf scheme was adopted but after some years of operation of the scheme it was found that it was failing to be fully effective because of faulty distribution. In consequence a new scheme of distribution was devised and is described in this article.

It is based on a novel application of punched-card accounting machines which themselves are fundamentally controlled by relays operating on timed cycles.

Distribution of Instructions.

With the introduction of the scheme of loose-leaf instructions a method of distribution was introduced based on three principles :— restriction by subject, restriction by grade, and recording of holders of instructions. An instruction in the loose-leaf scheme is known by its designation which consists of division, sub-division, section and number. As an example, in the designation TELEPHONES, General, D 6011 the parts are :

Division—TELEPHONES
Sub-division—General
Section—D
Number—6011

The unit for distribution purposes was the sub-division, subject to certain broad restrictions by grade of user, indicated by the " circulation letter " printed on each instruction. The ten circulation letters included only three relating to workmen, one for " external " workmen, one for " internal " workmen and one for all workmen.

A manuscript record was kept at each Section office of each individual or group to whom instructions were sent, together with particulars of the sub-divisions with which the particular users were concerned and new and amended instructions were distributed according to that record. This scheme had one major and several minor disadvantages. The major disadvantage was that within the largest class of user—workmen—there was (apart from division into " internal " and " external " men) only one restriction, that by sub-divisions, and with the growth of the number of instructions—this meant that a workman requiring instructions on one aspect of a subject, and therefore receiving all those workmen's instructions in the related sub-division, would probably receive many instructions in which he had no interest. Among the minor disadvantages were :—the difficulty of deciding the sub-divisions appropriate to a particular job, and of keeping records amended as the issue of new instructions made fresh sub-divisions necessary ; the necessity at headquarters of issuing an instruction in a particular sub-division so that it would reach the users of the sub-division ; and the relative uselessness of certain circulation letters.

Various ways of improving the position were considered. The biggest need was to effect some discrimination between various workmen to make distribution to them more selective. It was finally decided that satisfactory results could be obtained only by distribution on a strictly functional basis. This conclusion was supported (a) by the knowledge that the South African P.O. was using on its E.I.s circulation letters some of which signified grade distinctions as in the British P.O., whereas others signified restrictions according to certain simple functions, e.g. all jointers, and (b) by the fact that in the North Wales District it had been found desirable to prepare lists of those E.I.s considered proper to various classes of work. It was obviously undesirable that the reading and classification of E.I.s as issued should be carried out simultaneously in fifteen Districts and moreover the scheme as commenced in North Wales covered only a limited portion of the Engineering Department's activities.

The work of the Department was therefore analysed and classified, the idea being that the ultimate unit should be an item of work which is undertaken as a whole by one man or a group of men and is not normally sub-divided. With this end in view these elements of work were named " basic duties." The full load of one man may then consist of one basic duty or a combination of several. As a result of this work a list of approximately one hundred technical and twenty clerical basic duties was prepared and with minor modifications and additions the list still stands.

Typical basic duties are :—

B.D. No. 1—Installation and maintenance of subscribers' apparatus, direct exchange lines.
B.D. No. 11—Installation of U.A.X. No. 12.
B.D. No. 49—Advice note and minor works control centre procedure.
B.D. No. 67—Radio interference investigation.
B.D. No. 87—Maintenance of stamp - selling machines.
B.D. No. 96—Construction of overhead plant.
B.D. No. 121—Clerk of Works, duct and manhole works.
B.D. No. 158—Clerical duty, cashier.
B.D. No. 171—Clerical duty, stores.

In addition to the basic duty numbers, a few letters are used to indicate blocks of numbers or to indicate that an instruction is to be circulated but is not to be filed except in complete files. For example, distribution letter F indicates circulation without retention to all clerical staff. Much advice and help in this work, the groundwork of the scheme, was given by Mr. L. G. Semple and the list before final adoption was discussed with representative Districts and Regions.

It being agreed that distribution according to these primary functions should be made, it was then necessary to decide the means. It was decided to provide a set of instructions at each man's headquarters or at his place of work, and that the set should include only those instructions directly relating to the man's work, expressed in terms of basic duties. The requirements of all men using a common headquarters or working in the same place were, in general, grouped. A set of instructions provided for one man or for a group of men is known as a file, is given a serial number and has its contents expressed in terms of basic duties. It seemed obvious that it would be necessary to have one record for each file of instructions. It seemed also fairly clear that it would be necessary to indicate on each E.I. issued the basic duties concerned and to distribute it only to the files used by those of the staff concerned with the particular basic duty or duties indicated. The problem lay in how the records should be analysed to determine the distribution of each instruction issued. Purely manual analysis of scheduled records being obviously unworkable, card record schemes were considered.

Consideration was first given to the use of cards with edge clippings indicating basic duties. This was found to be unsatisfactory because of the size of the card required to record the necessary information. Cards of such a size would have been difficult to handle in batches and moreover renewals of cards due to wear or amendment would have been expensive.

It appeared necessary, therefore, to employ a scheme using the whole surface of each card, to make better use of the size of card employed. Such a system, intended for manual operation, was considered and rejected, partly on account of the limited capacity of the largest standard card available but primarily because of the high cost of card renewals which would obviously be necessary to cover amendments to records and whatever damage might occur in use. This left only the machine-accounting systems to be considered. Of these there are two, Hollerith and Powers-Samas. Both use similar cards, $7\frac{3}{8}$ in. $\times$ $3\frac{1}{4}$ in. and smaller, punched in a similar fashion with holes, the significance of each of which is determined by its co-ordinates in relation to the edges of the card. In each system analysis is made by passing the card through a machine, the fundamental difference between the systems being that in the Hollerith machine the basis of operation is electrical whereas in the Powers machine the basis of operation is mechanical.

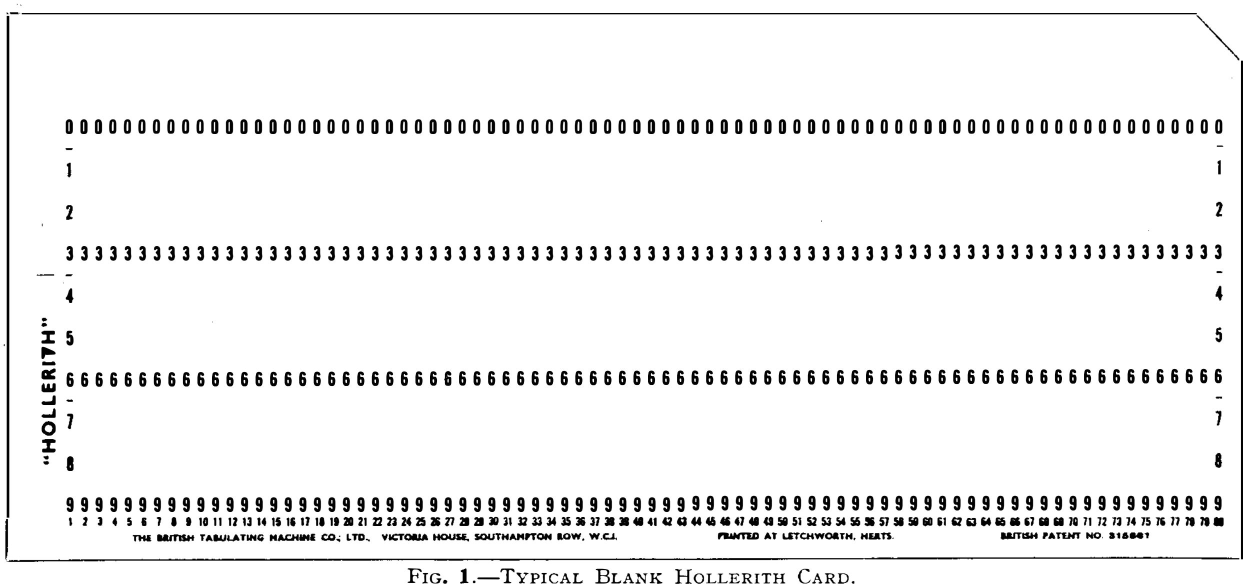

FIG. 1.—TYPICAL BLANK HOLLERITH CARD.

A typical blank Hollerith card is shown in Fig. **1**. This is the largest size and has eighty columns in each of which a hole may be punched in one of ten (or sometimes twelve) positions. In normal commercial use these cards may be used to record figures to be added to or subtracted from other figures, information to be printed or information which is to be stored until required. When it is necessary to extract particular cards from a number they are sorted for compliance with certain conditions. This is done, in both systems, by causing the selecting device to operate on a particular column in each card ; the operation of the selecting mechanism distributes the cards into boxes according to the position in the column concerned in which each is punched. An additional facility in each system makes it possible to select all cards which comply with each of eight predetermined conditions. Neither of these standard facilities would make it possible to obtain without repeated sorting of the cards the information required in the Engineering Department since it was necessary to determine which of several cards, representing files, were punched in one or more of certain positions, representing basic duty numbers allotted to the E.I. to be distributed. An example will perhaps make this clearer :—

Assume three files exist, to which the following basic duty numbers have been allotted as representing the work of the users :—

File No. 1—Basic duties 1, 7, 16.
File No. 2—Basic duties 4, 5.
File No. 3—Basic duties 2, 5, 6, 21.

Now assume an E.I. is issued to which the basic duty numbers 5 and 21 have been allotted on the strength of its contents. The selecting arrangements must obviously pick out all those cards representing all files to which basic duty numbers 5 or 21 or both have been allotted. Therefore files 2 and 3 will be selected and the fact that file 3 is twice qualified makes no difference. Since the total number of basic duties created was about 120, not including spare numbers, it was necessary that the selecting device should be capable of picking out, in one operation, all cards punched in one or more specified positions out of 120. Moreover, since it was not necessary to examine the actual cards but only to obtain from them particulars of the files represented, it was desirable that the arrangements should be such as to extract the required information from the chosen cards as they pass through the machine without upsetting their sequence, thus avoiding the necessity for re-sorting which normally follows every sorting operation. This facility exists in the listing-sorting machine made under each system.

The requirements for this particular scheme were referred in turn to the makers of each type of machine. After consultation, a design meeting all requirements was evolved by the British Tabulating Machine Co., the makers of the Hollerith electrically-operated machines. From the investigations made during that period it appears that the Hollerith system is the more flexible of the two as regards provision of non-standard facilities because much can be accomplished by circuit changes which could only be achieved in the mechanical system by redesign of machine parts.

Principles of Hollerith Machines.

The essential principle upon which the operation of Hollerith machines depends is the operation or non-operation of relays or solenoid-operated mechanisms at fixed times in a cycle of operations.

A card which is being analysed passes between a series of wire brushes and a roller. (Fig. **2**). The card

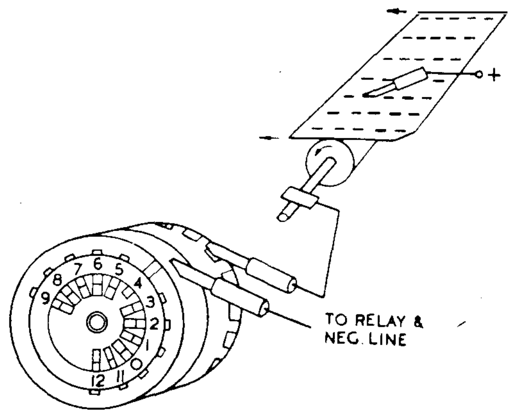

FIG. **2**.—PRINCIPLE OF SELECTION.

feeding device is geared to the main drive and timing shaft of the machine and the card moves so that the brushes run along the card columns. When a hole has been punched in a column a circuit is completed from brush to drum at the time the hole comes under the brush. Master contacts operated by cams geared to the main shaft break all brush circuits before they can be broken by the card at the trailing edge of a hole and also ensure that the brushes are live only when a card is between them and the roller.

In the next four paras. an outline is given of the operation of standard Hollerith machines so that the origin and development of the special machines in use in the Engineer-in-Chief's Office will be clearer.

In a standard sorting machine cards are analysed column by column only. A single brush is used which runs on the column being analysed. The card receptacle consists of thirteen compartments (one for each digit) from 9 to 0, X and Y and one for " rejected " cards—i.e. cards unpunched in the column in question. Two of the compartments (corresponding to the X and Y positions) are used only when pence, months, or similar items involving twelfths are involved. The timing, relative to the passage of the card, of the pulse which occurs when a hole passes under the brush determines the compartment into which the card is guided, and hence each card is deposited in the receptacle corresponding to the number punched in the column being dealt with.

In the brush circuit is a rotating switch, not unlike a Baudot distributor in construction. Shown schematically in Fig. **2**, it consists of a drum of insulating material into which have been moulded a ring of copper and twelve segments (see Fig. **3**). Each segment

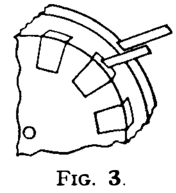

FIG. **3**.

can be connected to the ring through an individual switch incorporated in the drum and the circuit is completed through two brushes which bear on the ring and on the segments respectively. The drum is geared to the main drive and so, by presetting the drum switches, the card brush can be made live as certain predetermined positions on the card pass beneath the brush. It is thus possible to pass into the card boxes only those cards punched in certain positions and to reject the remainder.

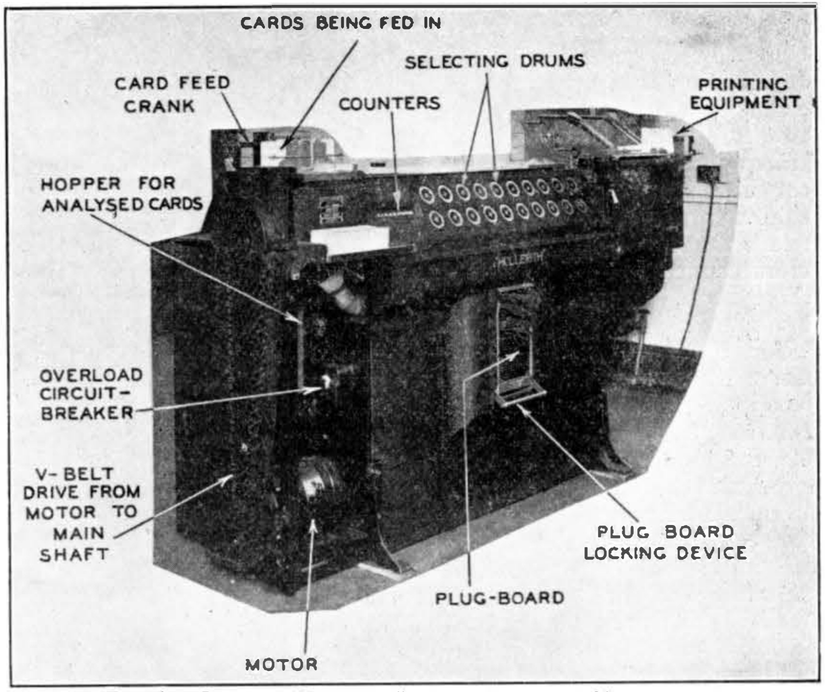

FIG. 4.—GENERAL VIEW OF SELECTING-LISTING MACHINE.

Ordinary Processes Employing Accounting Machines.

In ordinary applications, it is usually necessaıy to do one of two things—to sort cards into numerical order according to the particulars shown in one or more columns, and probably to count the cards or items concerned, or to perform arithmetical functions with the information concerned. In either case the results may be obtained from inspection of counters or by final manual and visual analysis, or in the form of a printed record obtained from the machine equipment. With a standard sorting machine as just outlined the order of cards is disturbed in the process and cards must afterwards be re-sorted to put them in their original order. Moreover this does not cater for cards punched in two or more positions in one column as any such card is treated as though it were punched only in the hole which reaches the brush first.

In a tabulating machine the counters and printing equipment are set to operate on certain columns and the whole of the information included in those columns is dealt with in the same way. Machines have been developed which will extract the information only from cards meeting a predetermined combination of conditions with a maximum of eight but such machines can be used only when the whole of the combination applies and eight would not, in any case, have been sufficient for the requirements of this particular job. When a machine prints totals only the process is known as tabulating, but when every item dealt with is printed, the process is known as listing.

Principles of the Special Selecting-listing Machine designed for E.I. Distribution.

This machine combines the discrimination of a sorter with the information-extracting and printing functions of a listing tabulator and makes it possible to extract and print information from selected

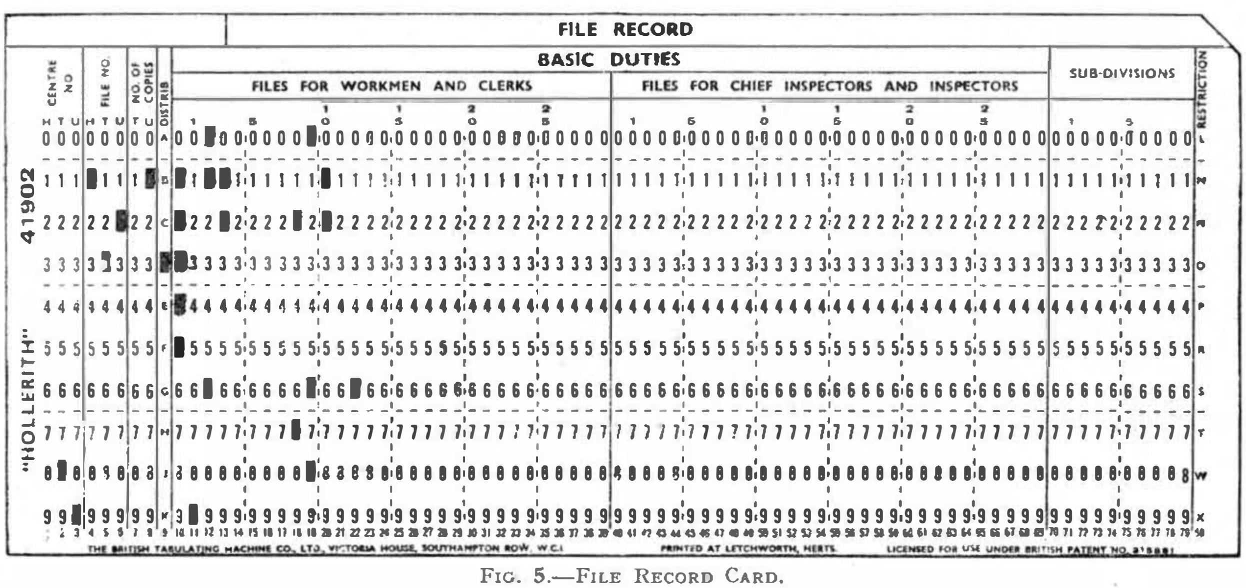

FIG. 5.—FILE RECORD CARD.

cards without disturbing their order, thus eliminating re-sorting.

Fig. **4** is a general view of one of the machines. It is equipped with two sets of eighty brushes, each complete with bronze roller, card-feeding equipment, twenty selecting drums (the rotating switches illustrated in Figs. **2** and **3**), plug board for changing connections, platen and eleven-column printing equipment, in addition to the motor, gearing and relays found in all similar machines. The necessary cross connections on the plug board are made by short flexible cords terminated at the ends with small brass plugs.

Fig. **5** shows the card used to record details of a file of E.I.s as punched for a typical file. On it are recorded, from primary documents supplied by the Districts, the numbers of the distribution centre and file, the number of copies required, the distribution letters and the numbers of the basic duties representing all the work of the file users. It is important to notice that as it is only necessary to record one number for each of the first three items on the card a decimal recording can be used—i.e. one column for the hundreds digit, one for the tens and so on. For the recording of basic duties it is necessary to have one position per number as otherwise wrong results would be obtained—e.g. if on a decimal system nos. 87 and 63 were recorded on the same card the punching would also correspond to Nos. 83 and 67.

The cards are stacked on the table shown to the top left-hand of the machine (Fig. **6**) and a presser-plate holds them against the feeding device, which is illustrated in principle in Fig. **7**. The cards are approximately seven mils thick and the cross-piece has on it a ledge or knife about four mils deep which when at the top of its travel engages with a card and drives it into a nine-mil throat where it is picked up by feed rollers. The card then passes between the upper set of eighty brushes and the corresponding roller. At this stage the card is " selected " or " not selected " but the process is electrical and the feed rollers keep the card moving vertically downwards, edgewise.

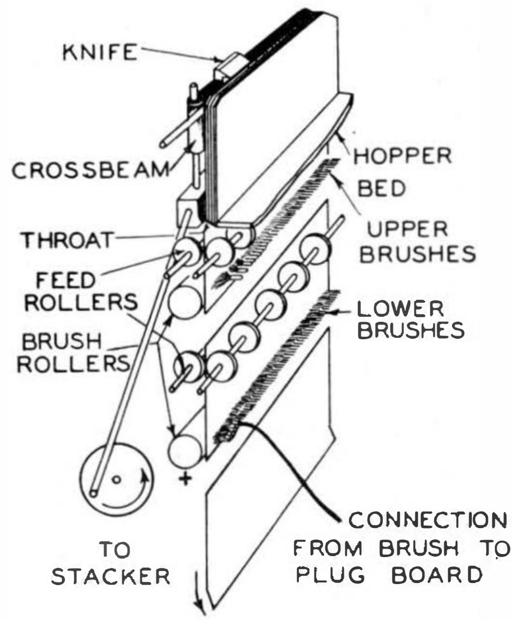

FIG. 7.—FEEDING AND SELECTING ARRANGEMENT.

It then passes between the second set of eighty brushes and the corresponding roller. At this point the information which is to be printed is extracted, but only if the card has been selected at the preceding stage. The card passes on and is automatically stacked in a hopper so that the cards end in the same relative positions as they started. It is necessary to remember that all cards are handled in the same way, hence the elimination of any need for re-sorting into original order.

Considering in more detail the operation of the machine, it is necessary to return to the upper roller and brushes. To set up the machine for an ordinary distribution job, circuits are completed via the plug board, using double-ended flexible leads, in accordance with details of the E.I. to be distributed. As will be seen from Fig. **5** one column of a card covers ten basic duty numbers. A drum is connected in series with each brush belonging to a column in which is one of the basic duties to which the E.I. applies. The drum is then set so that it provides a circuit for the appropriate unit digit of the duty number concerned. All the drum-brush circuits are paralleled at one side and the roller forms a common connection on the other (see Fig. **14**). The paralleled circuits are connected to a common selecting relay and so, if any hole in a card corresponds to one of the basic duty numbers applying to the E.I., the selecting relay is operated. The card passes on to the second set of eighty brushes. Those of the brushes which run on the columns from which it is desired to print information—for an ordinary distribution the columns are 1 to 8 inclusive—are connected by cross-plugging on the plug board to the printing mechanism. If the card has been selected at the previous stage, circuits are completed from

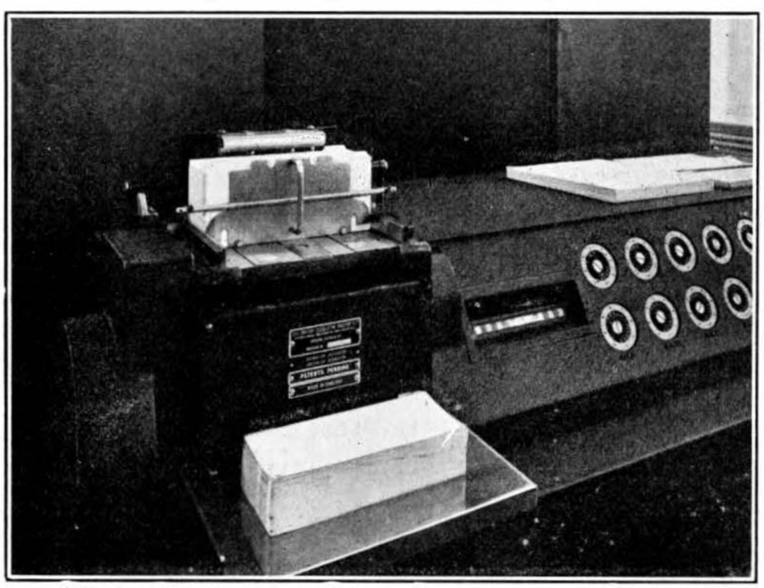

FIG. 6.—CARD-HANDLING END OF SELECTING-LISTING MACHINE.

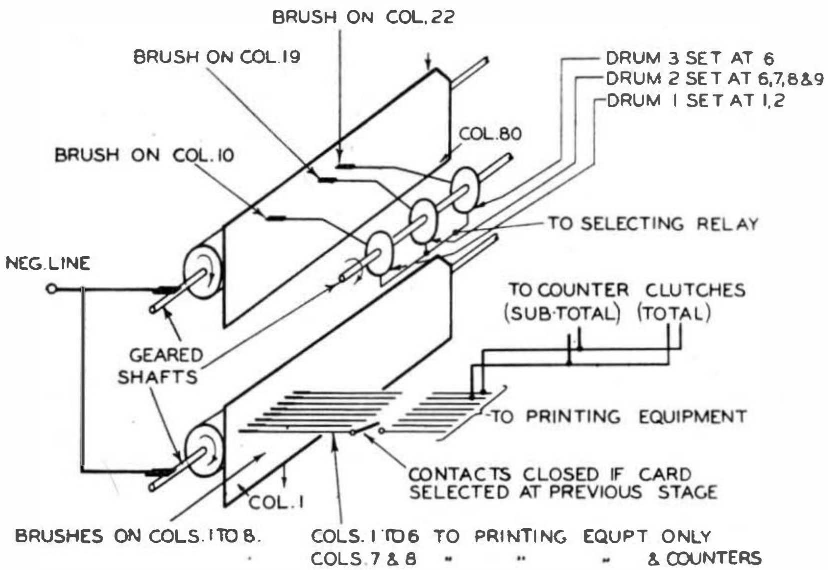

Fig. 8.—Preparation of Waybill.

the roller, through holes in columns 1 to 8 of the card and the respective brushes, to the print unit and the counter ; particulars from the card are then printed on the list of files requiring copies of the E.I. and the number of copies indicated on the card is added to the total for that distribution centre and to the grand total, which determines printing requirements. The result of the operation is a way-bill for each distribution centre for the E.I. in question.

The process is illustrated in Fig. **8**.

The printing mechanism (Fig. **9**) and counting mechanism operate through cycles controlled by contacts operated by cams geared to the main drive. The machine tends to put the printing mechanism into operation every cycle—i.e. every time a card passes through the machine—but operation is suppressed except when the selecting relay has been operated by a card passing the upper brushes. When the printing mechanism is allowed to operate each type bar rises until the brush in the lower set on the corresponding column reaches a hole in the card ; a detent is then operated, the bar is arrested and the type head which is opposite the centre-line of the platen is struck by a hammer (Fig. **10**).

The cards are fed through the machine so that the numerals on the cards reach the brushes in the order 9, 8, 7, . . . 1, 0. For this reason the number 9 is at the top of each type bar.

The counters consist of one unit per digit. Each unit comprises an adding wheel on which the digits appear, a clutch wheel and a commutator (Fig. **11**). The adding wheels are equipped with carry-over levers to provide for carry-over within any one counter.

Adding wheels are operated by clutching them to a shaft geared to the main drive. Each wheel has a separate electrically-operated clutch to which connection is made through the plug-board. When a wheel is connected to a column brush the clutch is energised as soon as a hole appears under the brush—i.e. it is engaged early in the cycle when 9 is punched and late in a cycle when 2 is punched. The wheel is then rotated a corresponding number of tenths of a revolution and at the end of the cycle all clutches are released. The commutator is a marking device used for transferring to a printing unit the reading of a counter. The commutator consists of a conducting semi-circle and a non-conducting semi-circle with ten contacts (Fig. **11**). A pair of conducting brushes is rotated when the clutch is engaged and the contact which the brushes mark indicates the reading of the adding wheel. When it is necessary to print the reading of the counter the print magnet for the appropriate type bar is connected through the commutator to a similar rotary commutator which is driven in step with the lifting of the type bars. When the driven commutator reaches the contact marked by the commutator associated with the adding wheel the circuit for the print magnet is complete and the corresponding figure is printed.

Because of the mechanical operations concerned the printing mechanism cannot be operated at as high a speed as is suitable for selection. A two-speed drive is therefore necessary and so a compound-wound motor is employed and when a card is selected a resistance in the motor shunt field is short-circuited and the speed is halved. The motor is operated on 230V D.C. and the same supply is used for the relays and other magnets, precautions being taken in providing a supply to ensure that current surges

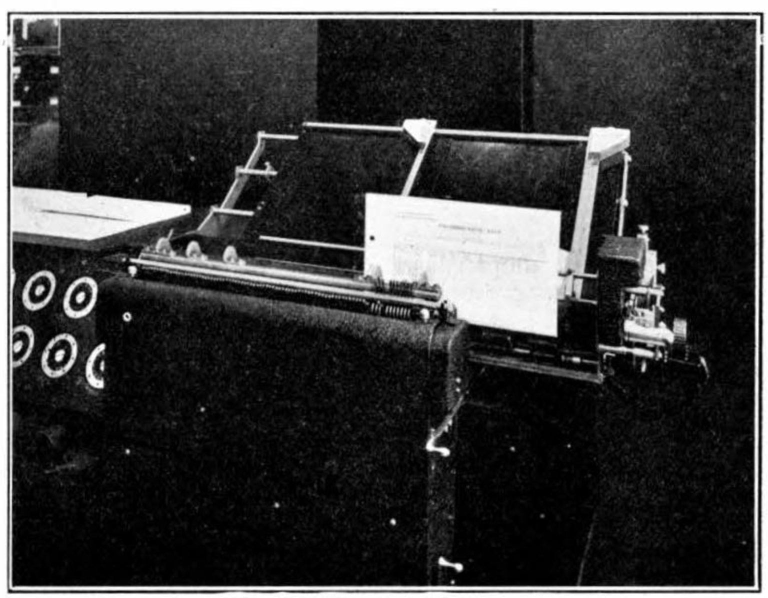

Fig. 9.—Printing Equipment.

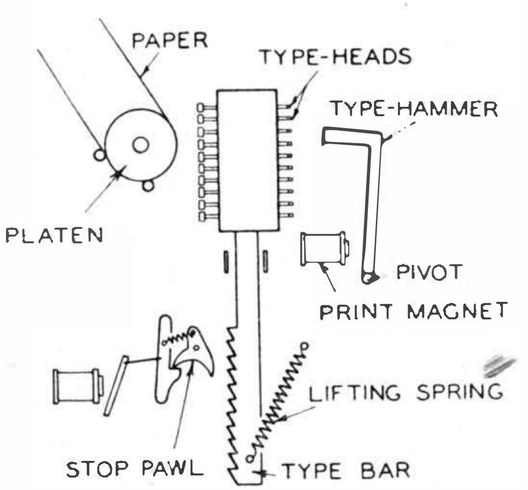

Fig. 10.—Printing Mechanism.

due to the motor do not cause appreciable voltage drop in the relay circuits.

The average time required to prepare a complete set of waybills covering the distribution of an E.I.

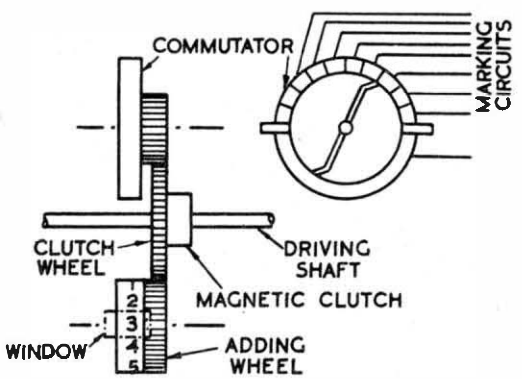

Fig. 11.—Principle of Counter.

to those files concerned, out of a total of approx. 16,000, is 2¾ hours. The preparation of a composite list of the E.I.s appropriate to a particular file takes about ¾ hour.

Relays.

The relays used by the machine makers appear strange to those familiar with telephone relays. Two types are illustrated in Fig. **12**. The coils are wound with enamelled wire laid up with strands of cotton as insulation, the whole being impregnated and baked. The springs are of steel (8 mils thick on the small relay and 14 mils on the large relay) and the contacts of pure silver. No facilities exist for setting springs and gap adjustments are made by the use of heavy backstops. The voltage between open contacts may be 250 (D.C.) but arrangements are made, wherever possible, to break circuits on cam-operated contacts (tungsten) which are renewed as necessary. The average life before failure of silver relay contacts in these machines is stated to be 20×10^6 operations. No figures are available for the tungsten cam-operated contacts.

Operating times are stated to be :

	Operate	Release
Small relay—change-over contacts	5·5	5·5 mS
Large relay—change-over contacts	17	10 mS

Extensions of Original Scheme

Distribution by Sub-divisions.

For the convenience of Headquarter officers who prefer to obtain E.I.s by sub-divisions the scheme has been extended to cover this facility and sub-divisions are in such cases recorded by code numbers on the file cards (see Fig **5**) and analysis is made accordingly by setting up a drum and brush on the appropriate column.

Preparation of Index Lists.

It was early found that it would be very useful to be able to produce a list of the E.I.s appropriate to any basic duty or file. To do this by hand would have required considerable laborious clerical work and so a method was devised for doing it by machine.

A card was prepared for each E.I. using the card designed for file records, with minor modifications, the designation of the E.I. being shown in code form (see Fig. **13**). The code, in full, consists of ten digits. The sub-division requires two digits—e.g. GENERAL, General, is 01, TELEPHONES, Automatic, is 58 and WORKS, Execution, is 86. The section requires two digits, numbers from 01 to 26 being used for section letters from A to Z. The next four digits are the serial number of the E.I. and the last two digits show the issue number. (No provision has yet been made for issue numbers greater than 99). If all the pages are

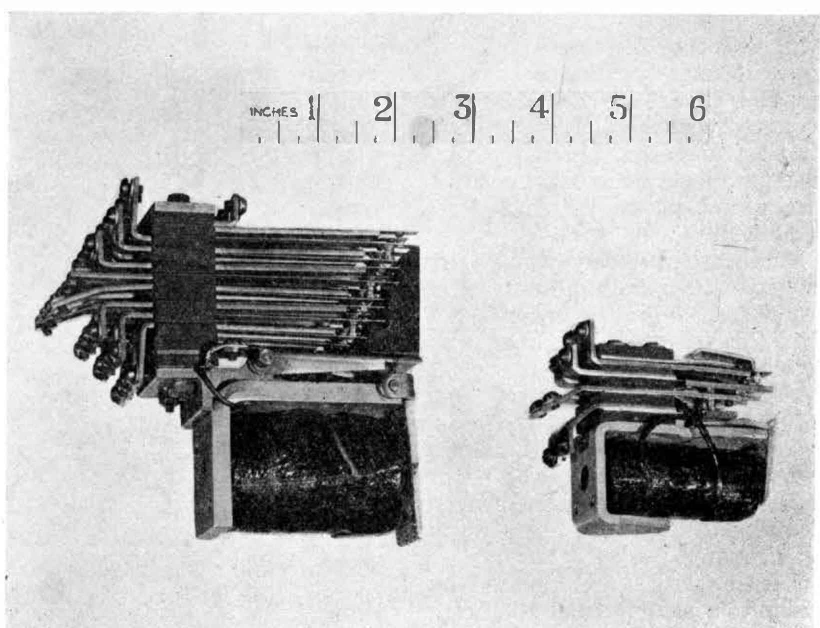

Fig. **12**.—The Two Types of Relay Employed.

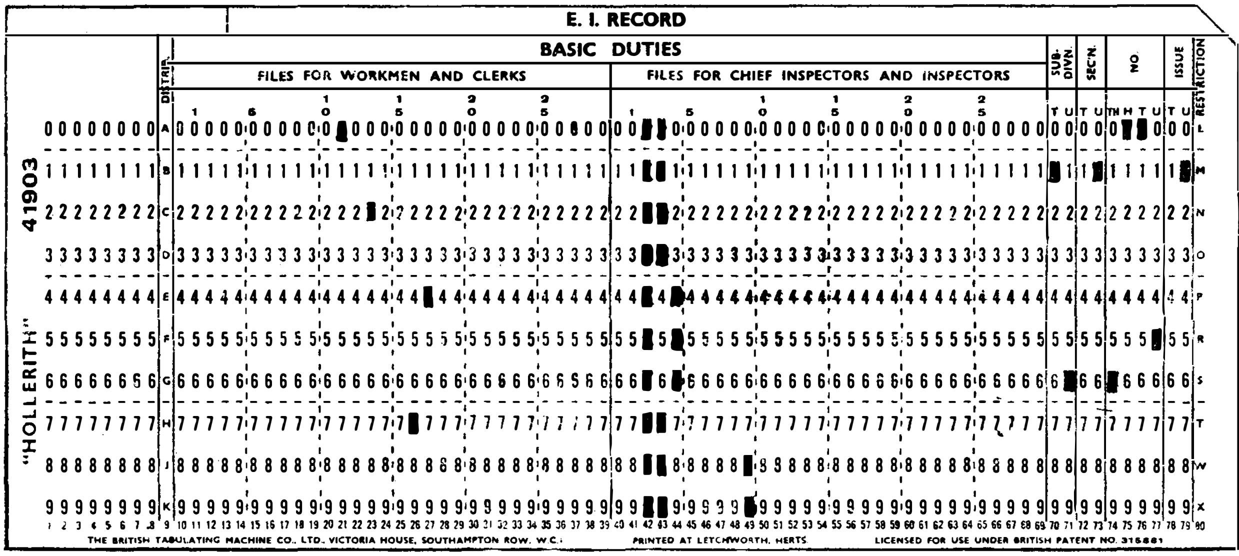

FIG. 13.—E.I. RECORD CARD.

not of the same issue 00 is punched and reference to a separate list is necessary.

Thus, as an example, E.I. TELEPHONES, Automatic, G 5001, issue 5, would be shown in code as 58 07 5001 05. By setting the machine to select all cards punched for a particular duty number (for a list of E.I.s for that basic duty) or for any one of a combination of basic duties (for a list of E.I.s appropriate to a file) and arranging to print from columns 70 to 79 the coded designation of each E.I. (including the number of the latest issue) a list of E.I.s is easily prepared. These lists are invaluable in compiling or checking files of E.I.s.

Common Composite File Lists.

When it had been decided to prepare lists of the E.I.s appropriate to certain files it was immediately realised that certain combinations of basic duties recur quite frequently and that therefore one duplicated list would serve for all such files. The problem then was to determine to which files common combinations of basic duties applied without checking the 16,000 file records by eye and hand. It was found that the machines as originally designed could not do that work, but a relay set was designed, and built in the Post Office Circuit Laboratory, which, in conjunction with one of the machines, made it possible to do the analysis by machine. Fig. 14 illustrates the normal distribution connections, some

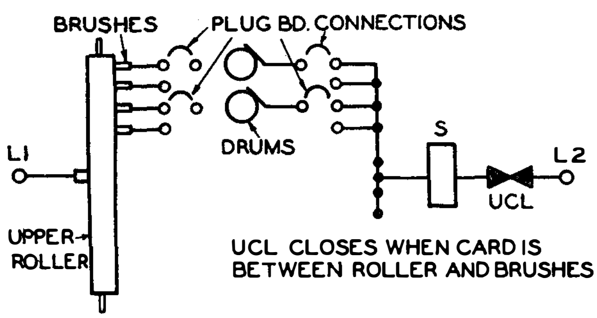

FIG. 14.—NORMAL SELECTING CONNECTIONS FOR DISTRIBUTION WAYBILL.

or all of the twenty drums being plugged to a corresponding number of the eighty upper brushes as required. The circuit with the added relay set is shown in Fig. 15, only five drums being illustrated. The

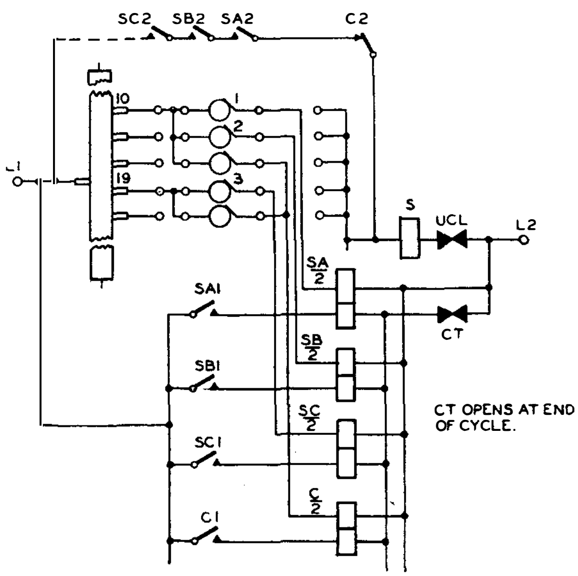

FIG. 15.—CONNECTIONS FOR SELECTION OF COMMON COMBINATIONS OF DUTIES.

circuit operates as follows :—Assuming it is desired to find all those files to which a combination of basic duties applies, say 1, 2, 96, 97, 98, 99, 126, relays SA to SG are each connected to a selecting drum and an upper brush as shown below.

Relay SA. Connect to drum 1, set at 1, and to brush 10

Relay SB. Connect to drum 2, set at 2, and to brush 10.

Relay SC. Connect to drum 3, set at 6, and to brush 19.

Relay SD. Connect to drum 4, set at 7, and to brush 19

Relay SE. Connect to drum 5, set at 8 and to brush 19
Relay SF. Connect to drum 6, set at 9 and to brush 19
Relay SG. Connect to drum 7, set at 6, and to brush 22

It will be seen from this that any card which is punched for basic duties Nos. 1, 2, 96 to 99 and 126 will allow relays SA to SG to operate when the card is passing between the roller and brushes. Each relay holds, after operation, via one of its own contacts and one winding. This provides a series connection from L1 to L2 via SA2, SB2, . . . SG2, S relay and UCL, and allows relay S to operate, thereby establishing the "selected" condition in the tabulator. A cam contact CT in the machine then breaks the holding circuit of relays SA to SG which release in readiness for the next selecting operation, and the selected card is listed as it passes between the lower roller and brushes. It will be obvious that unless a card is punched for each of the required basic duty numbers the series connection between L1 and L2 via relay S cannot be established and the card is not listed.

This arrangement does not, however, meet all the requirements because any card which is punched for other basic duties in addition to all those chosen will be listed. The rejection of those cards is arranged by connecting relay C as follows:—

Relay C. Connect to drum 8, set at 3 to 0 inc., and to brush 10.
Relay C. Connect to drum 9, set at 1 to 5 + 0, and to brush 19
Relay C. Connect to drum 10, set at 0 to 5, 7 to 9 inc., and to brush 22.

All the remaining upper brushes which cover the basic duty field on the card are connected direct to relay C. From this it will be seen that a card punched for basic duties other than 1, 2, 96 to 99 and 125 will allow relay C to operate and hold during the passage of the card between the upper roller and brushes. C2 breaks the series connection L1—relay S—L2, relay S cannot operate and the card is not listed.

Withdrawal Notices.

The scheme as described so far fully covers the information required for the construction of E.I. files and for the supply of waybills showing which particular files should receive copies of a new or amended E.I., but it was recognised in the early stages of preparation that any change on re-issue in the basic duty numbers allotted to a given E.I. would soon result in certain files holding up-to-date copies of the E.I. whereas others retained copies of an out-of-date issue. In the latter cases it is necessary to advise the users of the files that their copies of the E.I. concerned should be destroyed and it was first thought that analysis of the file records to determine the files affected would have to be carried out manually. The provision of the auxiliary relay set referred to earlier afforded a means of analysing the records by machine, and, in brief, this is carried out in the following manner.

Assuming issue 1 of a certain E.I. was allotted to basic duties Nos. 20 to 33, and that issue 2 was allotted to basic duties Nos. 20 to 25, 44 and 45 because of a radical change in the text of the instruction or for some other reason, any file which includes one or more of the basic duty numbers 20 to 25, 44, 45 in its composition will receive a copy of issue 2 of the E.I. whereas those files which include one or more of the basic duty numbers 26 to 33 will not receive a copy of issue 2.

Using the relay set in a manner similar to that for determining files of identical composition, the relay SA only is connected to the upper brushes so that it will operate on the passage of a record card which is punched for any of the basic duty numbers 26 to 33, and relay C is connected so that it will operate on the passage of a record card punched for any of the basic duty numbers 20 to 25, 44, 45. The operation of SA only will ensure the listing of the appropriate record card, and the operation of C will ensure that a record card is not listed. The list of files prepared in this manner is used for distributing the withdrawal notice.

Cancelled E.I.s.

The E.-in-C.'s Monthly List contains particulars of those E.I.s cancelled during the previous month and is useful for keeping up-to-date those files located in S.E.s', Sec. Engrs'. and similar offices. The list does not normally circulate to workmen, so that they cannot keep their files up-to-date from that source, and as these files constitute the greater proportion of the whole a special list of cancelled E.I.s is prepared monthly in E.I. form and a copy is supplied to the users of each file affected. The basic duty numbers allotted to each of the cancelled E.I.s are added together and form the basis for preparation of the relative waybills for distributing the information.

Tests Applied to Prove the Setting of the Machines.

Before any attempts are made to analyse records a special set of cards is passed through the machine to be used to prove that it has been plugged and set correctly in all respects. At the completion of each analysis the test cards are again passed through the machine and providing the same test results are obtained it is safe to assume that the analysis has been correctly carried out. The cards are punched in such a manner that the basic duty numbers and distribution letters (where applicable) which are to be selected by the machine are actually printed by the machine when it has been correctly connected up. The latest development in this direction is the printing of the basic duty numbers which are required to operate the C relay for those analyses where the special (auxiliary) relay set is utilised. Normally, of course, the operation of the C relay prevents any listing of cards. It has been made a principle that after the test pack has proved the connection as being satisfactory the setting of a machine must not be altered in any way until the analysis in hand is completed.

Life of Card Records.

It has been found that as a result of the care taken by the staff in handling the card records the cards will pass through the selecting listing machines 800 to 1,000 times before renewal is necessary. This performance is remarkable when it is considered that the majority of the cards pass through the machine at the rate of 200 cards per minute.

Punching of Card Records.

The preparation of the card records is an essential feature of any scheme such as this, although the scheme just described uses far less cards than most other applications of such machines. For most commercial applications of these machines a separate card is necessary for each primary voucher or each transaction. Each card must be punched and that part of the work may be of considerable magnitude, justifying the use of power-driven punches and/or pre-punching of frequently-repeated details in blocks of cards.

For the application just described the card requirements are small, since once the scheme was set up cards are only required to record changes in the basic duties applicable to E.I. files (i.e. changes in the work of the users), to add to the record of existing E.I.s or to replace worn out or damaged cards. When replacement of a complete pack is necessary it is done by the Stationery Office (or by the B.T.M. Co. in an emergency) using a power-driven reproducing punch and checking machine. All the other requirements are relatively small, total card requirements for purposes other than complete reproduction being of the order of 400 cards per month (all records being in duplicate). Hence the punching can conveniently be done on a hand-operated punch. It is possible to punch two cards simultaneously, thus halving punching time and ensuring identity of the two sets of records.

Possible Applications of Machines of This Type.

The selecting-listing machines just described were the first of the type to be built. The results obtained and the flexibility of the system of operation suggest that similar machines should be applicable to a wide variety of problems requiring analysis of information. For ordinary statistical analysis these machines have two main advantages over any other sorting machine or system known to the authors :

(1) The information required can be obtained as a printed record without disturbing the order of the card records. This saves time on re-sorting and makes possible the restriction of analysis to predetermined blocks of cards.

(2) The analysis can be made on a basis of finding all those records which comply with one or more of a given set of conditions or all those records which meet all of a given combination of conditions. A mixture of the two types of analysis is also possible. There would be no fundamental difficulty in building a machine which could make an analysis of any of the foregoing types, in respect of 800 items, in one operation.

One possible application to Post Office work which immediately suggests itself is in connection with fault analysis. For many applications of machine-accounting, details are entered on cards in manuscript, the information later being translated into punched holes in the same cards. By a suitable choice of layout this can be done without making the original manuscript entries illegible. It would seem feasible to use such cards in lieu of fault dockets, and to arrange for the cards to be collected, then punched and analysed at one or more points according to the amount of information to be handled.

The printed results of such analyses could then be duplicated for distribution.

Similar records and analyses in respect of the particulars of apparatus at each subscriber's premises might be advantageous ; although this would probably be useful if existing machines were available, the frequency with which analysis of such information could usefully be made would probably not be sufficient on its own to justify such a scheme.

Duplication of Machine Records.

The machines were designed to print on single or manifold paper, using ordinary typewriter ribbon. It has been found possible to cut stencils directly on the machines for reproduction by the Rotaprint or Gestetner processes or to eliminate the stencil stage and use sensitized aluminium plates provided a suitable lithographic typewriter ribbon is employed. The plates have so far provided the most satisfactory results, but this has almost certainly been due to the fact that the existing type faces on these machines are suitable for ordinary printing with ribbons but are not the most suitable design for stencil cutting. With suitable modifications to the type faces and perhaps to the type pressure, it should be possible to produce, as a routine matter without intermediate typing, duplicated printed records of the standard of rotaprinted E.I.s.

Tracing paper in conjunction with carbon paper arranged to give an impression on the back of the tracing paper has been used as a stencil in the preparation of listed information which has to be duplicated. The trials have so far shown that readable copies can be produced by this method, which with minor improvements will produce work comparable with the standard of normal rotaprinted work.

Acknowledgments.

The thanks of the authors are due to the British Tabulating Machine Company, Ltd., and in particular to Mr. J. O. Simpson of that Company, for the supply of drawings and information, much of which it has been impossible to include because of space limitations.

A "Chopped-Signal" Vacuum Tube Generator with Good Voltage Regulation

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U.D.C 621.396.615.11 621.395.645.331 621.395.631

Generators of interrupted signals and power amplifiers of good voltage regulation are frequently required in communications engineering. Thermionic devices are described which perform each of these functions and, as an example of their application, an experimental 500 c.p.s./20 i.p.s. generator is described which has a performance equivalent to that of the standard rotary machines.

Introduction.

THE original object of this investigation was to explore the application of thermionic devices to the generation of 500 c.p.s. signals chopped at 20 i.p.s. and having a voltage regulation comparable with that of the standard rotary machines. Such a generator will consist of two main parts :—

(*a*) a device generating voltages of the required waveform ;

(*b*) a power amplifier whose output voltage is sensibly independent of load variations within prescribed limits.

Both these units have application other than the production of 500/20 signals and will, in the first place, be described separately under the headings " Drive Stage " and " Output Stage."

It was considered that the lowest practicable anode voltage was 100 for, with lower voltages, it is impossible to obtain appreciable power output from existing valves. For the experimental work described it was assumed that a 50 volt negative and a 50 volt positive supply would be available and the units were designed on this basis.

It is of interest to note, in passing, that work has already been done on the related problem of a 500/20 valve generator for use where sinusoidal modulation is adequate and where power output and voltage regulation requirements are less stringent. Apparatus of this kind, suitable for installation at small terminal stations, has been designed and is referred to elsewhere.[1, 2]

THE DRIVE STAGE

General Principles.

Oscillogram 3 of Fig. 1 illustrates the waveform of the voltage to be produced by the drive stage. Here, periods of zero output alternate with periods of constant 500 c.p.s., A.C. output, each phase lasting 1/40th sec.

A voltage envelope possessing these characteristics can be derived from a continuous 500 c.p.s. oscillation by means of an " intermittent amplifier " whose amplification factor alternates at 20 c.p.s. between zero and a steady value with rapid transitions. A suitable arrangement for such an amplifier is shown in Fig. 2. Here, a 500 c.p.s. voltage is applied to the control grid of a pentode, provided with the usual self-bias resistance, and a 20 c.p.s. switching voltage is applied to the suppressor grid. The waveform of this voltage must be such that the suppressor grid has a constant potential in the vicinity of the cathode potential for 1/40th sec., followed by a further 1/40th sec. during which the suppressor grid is very negative with respect to the cathode ; a method of producing such a waveform will be described later. This principle of paralysing a pentode amplifier at will by the application of a negative bias to the suppressor grid is well known. It is used, for example, in the design of voice frequency signalling receivers in order to secure immunity from false operation by alien signals such as speech.[3, 4] Under

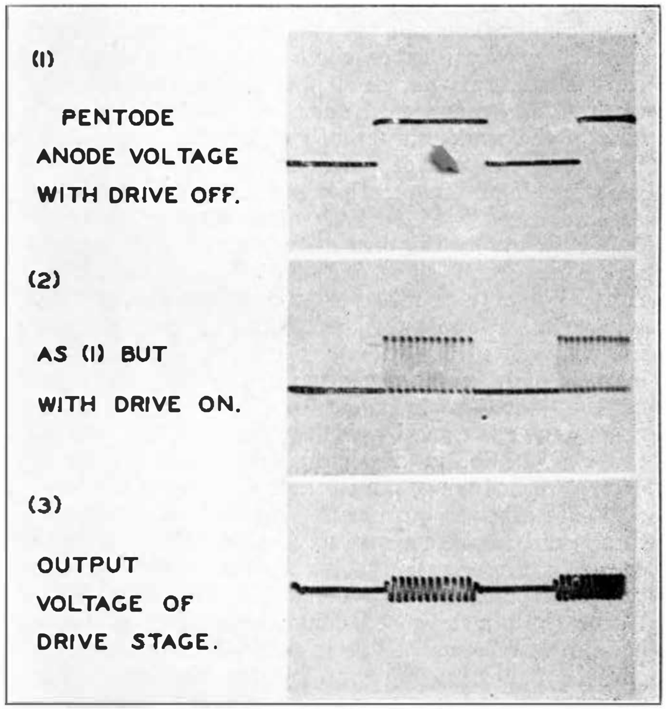

FIG. 1.—OSCILLOGRAMS OF DRIVE STAGE VOLTAGES.

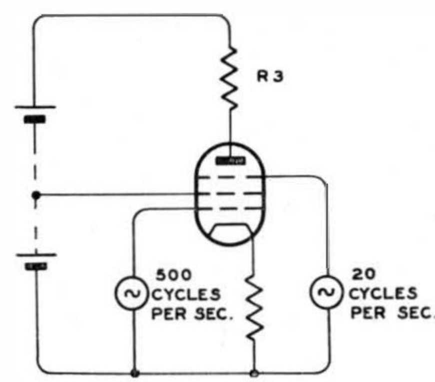

FIG. 2.—PRINCIPLE OF THE 500/20 INTERMITTENT AMPLIFIER.

[1] *P.O.E.E.J.*, Vol. 29, p. 225.
[2] The Physical Society, Jan., 1937. Catalogue of the 27th Annual Exhibition of Scientific Instruments and Apparatus, p. 176.
[3] *P.O.E.E.J.*, Vol. 29, p. 43.
[4] I.P.O.E.E. Printed Paper, No. 162.

the above circumstances the steady anode current through R_3 is of rectangular waveform and is shown in Fig. **1** (oscillogram 1), which was obtained by using the circuit of Fig. **2** with the 500 c.p.s. generator switched off. Here, periods of steady anode current alternate with periods of zero anode current. Oscillogram 2 (Fig. **1**) shows the result of switching on the 500 c.p.s. generator and is self explanatory.

Comparison of this waveform with that required (oscillogram **3**, Fig. **1**) shows that it is of the correct form except that it contains an unwanted 20 c.p.s. component of rectangular waveform. This is removed by connecting the filter shown in Fig. **3** across the

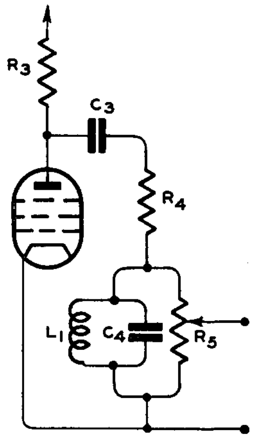

FIG. **3**.—FILTER FOR ELIMINATING 20 C.P.S. COMPONENT.

resistance R_3. This comprises a rejector circuit tuned to 500 c.p.s. in series with the resistance R_4. The circuit is heavily damped to avoid distorting the envelope of the impressed oscillation; a Q (i.e. quality = X/r where X and r are element reactance and total circuit resistance respectively) of **3** was found to be suitable and enabled a standard P.O. Coil Retardation No. 39A to be used. The resistance R_4 serves to reduce the voltage across the resonant circuit to a value suitable for application to the power amplifier. The condenser C_3 is kept small to assist the filtering of L.F. components. The output resulting across the potentiometer is illustrated by oscillogram **3** (Fig. **1**); no trace of residual 20 c.p.s. oscillation is observable.

In the intermittent amplifier already mentioned the switching voltage was derived from a sinusoidal oscillation by a distorting diode rectifier. This method might well be used here, except that it is difficult to produce a 20 c.p.s. resonant oscillator. Accordingly it was decided to employ a multi-vibrator, especially since this type of oscillator yields an inherently suitable waveform and, furthermore, can readily be synchronised with the 500 c.p.s. oscillation.

The Multi-vibrator.

The circuit is shown in Fig. **4**. Although the use of the multi-vibrator for the generation of harmonics is well known,[5] the physical considerations governing the shapes of the voltage waveforms produced do not

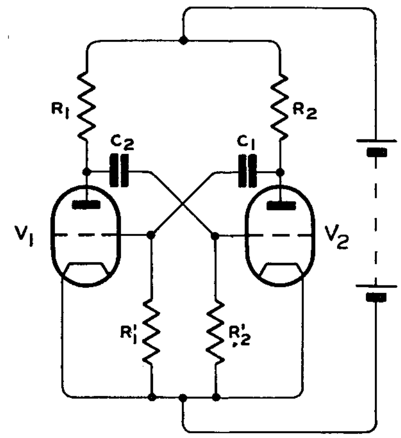

FIG. **4**.—THE MULTI-VIBRATOR CIRCUIT.

appear to have been clearly stated, and a brief discussion of its mode of operation may not be out of place.

Thus, suppose the grid of V_1 is considerably negative with respect to the cathode; the anode current of V_1 will be zero. Further, let it be supposed that the grid of V_2 is at cathode potential and V_2 drawing, therefore, a steady anode current. The negative potential on the grid of V_1 will decay exponentially with time since C_1 discharges through R'_1 in series with the joint resistance of R_2 in parallel with V_2. Meanwhile conditions in V_2 remain unchanged, and in due course the grid potential of V_1 will reach that negative value which corresponds with the inception of anode current in V_1. The anode potential of V_1 will then decrease and the grid of V_2 will become negative with respect to the cathode by virtue of the coupling circuit $C_2R'_2$. Correspondingly, the anode of V_2 and the grid of V_1 will become more positive, while the anode of V_1, together with the grid of V_2, becomes more negative. Thus the grid of V_2 becomes increasingly negative and so on; once current starts in V_1 it will increase at a very rapid rate, limited only by the (very small) time constants of R_1 and R_2 in parallel with their stray capacitances. This state of rapidly increasing current in V_1 will continue until the grid of V_1 reaches cathode potential. Very little further increase of the potential of the grid of V_1 is then possible, for grid current will begin to flow and will inhibit any appreciable rise. In general the parameters will be such that the current in V_2 is now zero, its grid potential being highly negative with respect to the cathode.

Conditions are now exactly those envisaged at the start, except that the valves V_1 and V_2 have changed rôles, and the process is repeated with a frequency which is closely related to the time constants of the circuits through which C_1 and C_2 discharge.

It follows that the grid voltage of either valve alternates between a sensibly steady value, approximating closely to the cathode potential, and a negative value which is initially great, but decreases exponentially with time until a certain point is reached where it changes quasi-discontinuously to its previous phase. Fig. **5**, oscillogram 5, illustrates such as waveform. The grid of the other valve executes similar oscillations 180° out of phase.

[5] See, for example, E. B. Moullin, " Radio Frequency Measurements," 1931, p. 125 and pp. 202-206.

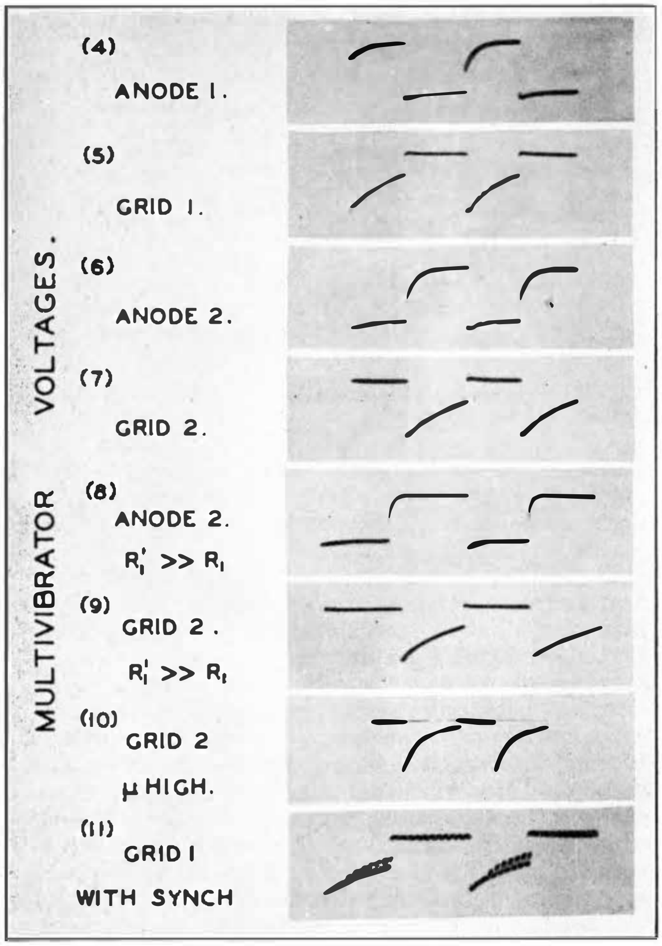

FIG. 5.—OSCILLOGRAMS OF GRID AND ANODE VOLTAGES.

Corresponding with such oscillations of grid voltage, the anode current will be of sensibly rectangular waveform, but the anode voltage will not be of rectangular waveform. This may readily be seen by considering the phase of rapidly decreasing currents in V_2. The load impedance of V_2 is R_2 shunted by stray capacitances; since these are very small the anode potential of V_2 rises very rapidly and continues to do so until the grid of V_1 reaches cathode potential. Thereafter, the grid of V_1 is effectively connected to the cathode through the comparatively high grid conductance of V_1 and, under such circumstances, the anode load impedance of V_2 is effectively R_2 in parallel with C_1. Accordingly, the anode potential of V_2 approaches battery potential exponentially with time constant approximately C_1R_2. Oscillograms 4 and 6 (Fig. 5) illustrate this initially rapid rise of anode potential, followed by such exponential segment. Comparison of oscillograms 4 and 7 (Fig. 5) shows that the ultra rapid change of anode potential covers a range of voltage equal to that covered by the grid voltage of V_2 between the values corresponding with the inception of current in V_2 and cathode potential.

Since the anode current of V_1 is necessarily of rectangular waveform, the balance of current in R_2, providing its exponential segment, must be drawn from the grid of V_1, and such current can only be drawn if the grid voltage of V_1 starts its new phase slightly above cathode potential, and decreases exponentially towards cathode potential. Hence the anode potential of V_1 will not be steady during the conducting phase, but will increase exponentially throughout that phase towards the steady value corresponding with zero grid potential. This form can be seen during the conducting phases of both oscillograms 4 and 6, but is not noticeable on the oscillograms of grid voltage, 5 and 7, since there it is of very small scale. It may be seen that the steady state is reached, to all intents and purposes, well before the termination of the conducting phase.

It is convenient to make $C_1 = C_2$, $R_1 = R_2$ and $R'_1 = R'_2$, and, further, to make $R'_1 >> R_1$, for then the exponential segments in the anode current, which are governed by C_2R_1, are short compared with the periodic time of the oscillation which is largely dependent on $C_1R'_1$. In the experimental arrangement to which oscillograms 4, 5, 6 and 7 relate, $C_1 = C_2 = 0{\cdot}1\ \mu F$, $R_1 = R_2 = 15{,}000$ ohms and $R'_1 = R'_2 = 0{\cdot}1$ megohms. Oscillograms 8 and 9 (Fig. 5) illustrate the improved squareness resulting from an increase of R'_1 and R'_2 to 0·35 megohms, the grid potential during the conducting phase approximating much more closely to the cathode potential throughout.

Returning now to the specific use of the multivibrator for providing a switching signal, it will be seen that the grid potential of either valve (oscillogram 5 or 7) is of suitable form. It has a phase where its value is sensibly that of the cathode, followed by one of almost equal duration where it is very negative. It is necessary that the grid should be at least 10 volts negative with respect to the cathode throughout the negative phase, otherwise cut-off in the intermittent amplifier will not be complete. The lowest negative value during this phase is the cut-off bias of either V_1 or V_2, corresponding with the battery potential applied to the anode: it is thus greatest with valves of low amplification factor (μ). The valve used for oscillograms 4–9 was of the low μ type (Mazda A.C./P1; nominal $\mu = 5{\cdot}4$); the result of using a high μ pattern (Mazda A.C.2/H.L.; nominal $\mu = 75$) is shown in oscillogram 10 (Fig. 5), where it may be seen that the negative bias falls exponentially to a few volts only before discontinuous transition sets in. Accordingly the A.C./P1 was used.

It is evident from the physical discussion of the operation of the multi-vibrator that the transition points can be synchronised by applying to the grids an oscillation whose frequency is high compared with the natural frequency of oscillation of the multivibrator. This follows since conduction in the non-conducting valve will be most likely to set in with positive peak values of the synchronising voltage and, once it has set in, it will continue, since the rate of change associated with the transition will be very great compared with the rate of change of the synchronising voltage in the vicinity of its peak value. Oscillogram 11 (Fig. 5) illustrates such synchronisation; the circuit used will be described later. This effect may be utilised to lock the multi-vibrator to the 500 c.p.s. supply which it is called upon to switch, thus preventing relative drift of the 500 c.p.s. and

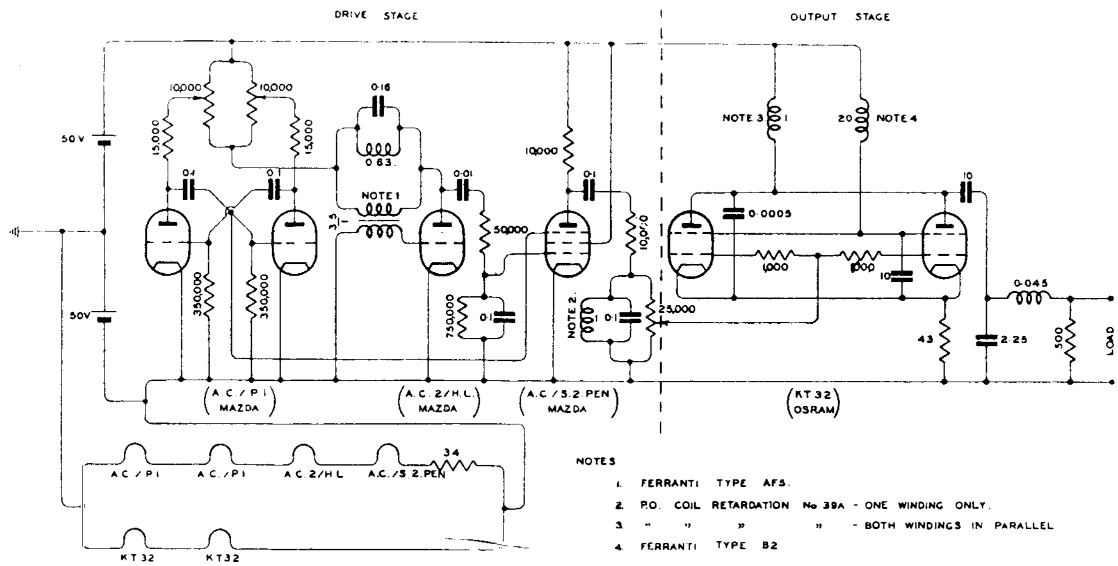

FIG. 6.—CIRCUIT OF 500/20 VALVE GENERATOR.

20 c.p.s. generators. Accordingly, the multi-vibrator is set to oscillate freely at about 17 c.p.s. and is speeded up to 20 c.p.s. by judicious introduction of the 500 c.p.s. synchronising voltage. Arrangements are made to energise the grids differently, if necessary, in order to achieve equality of the tone and no-tone intervals.

The Complete Stage.

The circuit of the complete drive stage is shown to the left of the dotted line in Fig. **6**. A steady 500 c.p.s. oscillation is supplied to the control grid of the Mazda A.C./S.2 Pen by a Mazda A.C.2/H.L. used as a simple self oscillator. Pre-set potentiometer feed is used, and automatic grid bias is provided by the 0·75 megohms resistance and its associated 0·1 μF shunt condenser. It may be noted that it has been found convenient to overdrive the A.C./S.2 Pen slightly, the pulses then produced being more closely rectangular. The waveform of the 500 c.p.s. oscillation is unimpaired since the harmonics introduced thereby are removed by the filter.

The multi-vibrator circuit has already been fully described and needs no further comment except to describe the means adopted for synchronisation with the 500 c.p.s. oscillation. The two paralleled 10,000 ohm resistances carry the oscillating anode current from the A.C.2/H.L., and the anode supply for the multi-vibrator is derived from their sliders; it is thus possible to inject into the anode circuit of each valve an adjustable 500 c.p.s. voltage which trips the device as already explained. The potentiometers are adjusted in turn until each operating phase lasts 1/40th sec. as seen by visual observation on an oscillograph.

The component values of the filter are chosen so that the drive voltage provided by the potentiometer can be adjusted over the required range.

THE OUTPUT STAGE

According to the specification for 500/20 generators, an output of 5·1 volts at 80 mA is required, both measurements being made with rectifier type instruments. Allowing for the "chopping" the maximum output required of the amplifier is 10·2 volts (R.M.S.) at 160 mA (R.M.S.), i.e. 1·63 watts. Assuming a minimum probable efficiency of the order of 20 per cent., the anode dissipation required in the power valve is 8·2 watts. Inspection of published data failed to reveal a pentode yielding this dissipation with an anode voltage of 90; it could, however, be achieved with two Osram KT32 tetrodes. These valves have characteristics of pentode type and are constructed in accordance with the "beam" principle

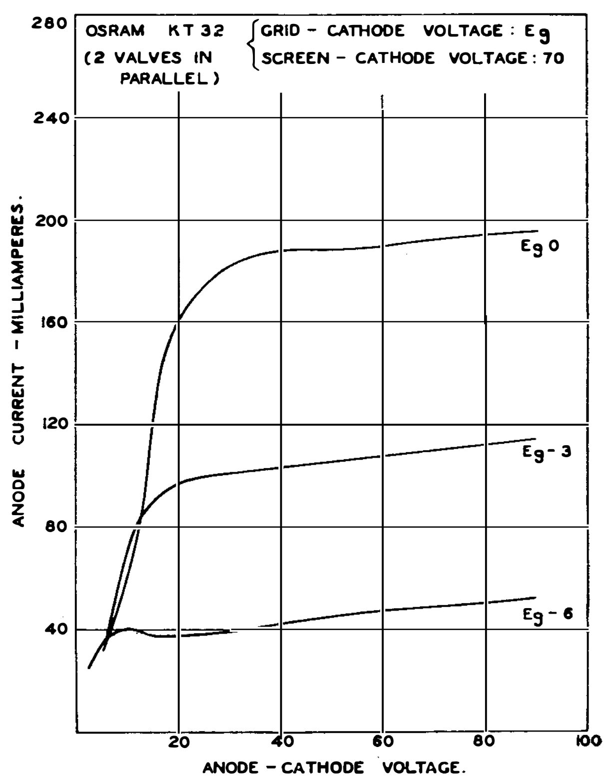

FIG. 7.—STATIC CHARACTERISTICS, NO BIAS RESISTANCE.

which has been discussed elsewhere, notably by J. H. Owen Harries[6, 7, 8], and by O. H. Schade.[9]

Fig. 7 shows a set of characteristics for two of these valves connected in parallel; the screen voltage was set at 70, not 90, to allow for inevitable loss of voltage due to bias and decoupling arrangements envisaged in the final design. The curve of interest is that with zero bias; the flat portion occurs in the vicinity of 200 mA. Hence the steady current under working conditions should be about 100 mA, which corresponds with an anode dissipation of 9 watts.

The circuit to the right of the dotted line in Fig. 6 was then set up. This is a "Variable Q" amplifier of the type recently described by the authors.[10] The grid resistances and the small condenser between anode and cathode were introduced to prevent parasitic H.F. oscillation. The bias resistance was adjusted to yield an anode current of about 100 mA, a value of 43 ohms being required. A fresh set of characteristics was then taken and is shown in Fig. 8, where anode current is plotted against anode-earth voltage for various grid-earth potentials. The screen-cathode voltage was held constant at 70 to simulate working conditions (since the condenser is connected between anode and cathode the screen-cathode voltage remains constant under working conditions, not the screen-earth voltage; the reason for this connection will be noted later). The curve with 10·5 volts positive bias

[6] *Wireless World*, Aug. 2, 1935, Vol. 37, No. 5, p. 105.
[7] *Wireless Engineer*, April, 1936, Vol. 13, No. 151, p. 190.
[8] *Wireless Engineer*, April, 1938, Vol. 15, No. 175, p. 212 (contains short bibliography).
[9] *Proc. Inst. R.E.*, Feb., 1938, Vol. 26, No. 2, p. 137.
[10] *Wireless Engineer*, Feb., 1939, Vol. 16, No. 185, p. 57.

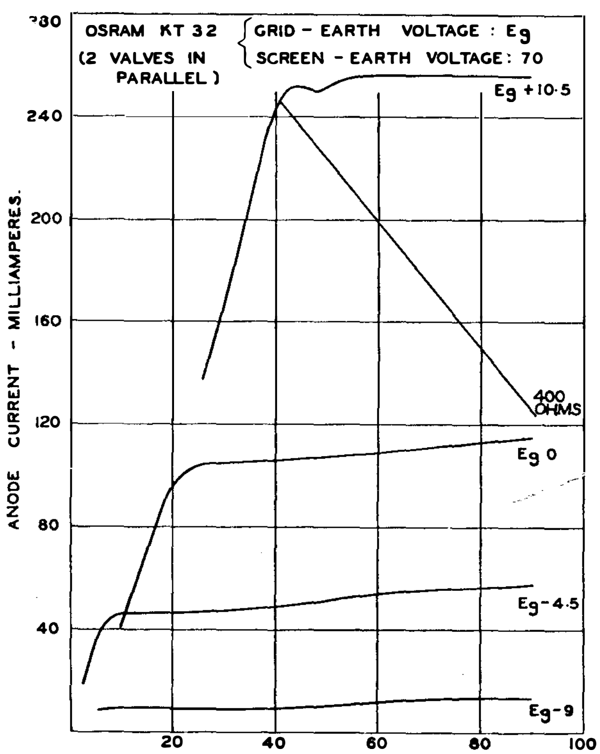

FIG. 8.—STATIC CHARACTERISTICS, WITH BIAS RESISTANCE.

is of greatest interest, since this corresponds with sensibly zero grid-cathode voltage (the cathode is biased positively with respect to earth by the resistance by an amount $0{\cdot}250 \times 43$, i.e. 10·5 volts). The knee of this curve occurs at about 40 volts, 250 mA so, with a steady current of 125 mA and 90 volts anode supply, the optimum load resistance R_o is $(90 - 40)/0{\cdot}125$, i.e. 400 ohms. This is sketched on the graphs. Comparison of the flat parts of Figs. 7 and 8 shows that the anode slope resistance is higher for Fig. 7 than Fig. 8. This results from the negative feed-back derived from the bias resistor, and obtains only if the screen current is by-passed from it. High anode impedance is essential to the satisfactory operation and hence the screen decoupling units were arranged as shown; inductive decoupling was used to avoid unnecessary loss of screen voltage.

It is required that the output voltage (E_r) on open circuit (R' infinite) shall be approximately 13; under these conditions, the load impedance of the valve is sensibly the condenser, since the choke is merely a decoupling unit, and is arranged to have an impedance much greater than that of the condenser. Hence, if X is the reactance of either element of the tuned circuit, the magnitude of the output voltage is XI or $I/C\omega$, where I is the R.M.S. value of the oscillating component of the anode current, and ω is $2\pi n$, n being the frequency.

But from the valve characteristics:

$$I = 125/1{\cdot}414 = 81{\cdot}5 \text{ mA}.$$

Hence

$$C = I/E\omega = 81{\cdot}5/(13.\ 6{\cdot}28.\ 500)$$
$$= 2{\cdot}2\ \mu F \text{ (approx.)}.$$

To facilitate construction from standard units a value of 2·25 μF was used. Thus X is 141·6 ohms, and the corresponding value of L is $1/C\omega^2$ and is 0·045 henry.

The specification of both these reactance elements requires considerable care if the performance of the completed stage is to be satisfactory. The coil was considered first and experiment showed that, where it is desirable that a coil shall remain of good quality, i.e. Q not less than 30 while carrying A.C. of magnitude greater than a few milliamperes, the most satisfactory construction appears to be achieved by employing a gapped laminated core of mumetal. The cross-section of the core is ½ inch square, and the stampings are " E " type, 5 mils thick, and are enamelled on one side; the gap is nominally 60 mils, as compared with the more usual 10 mils, but is adjustable in order that the resonant frequency of the circuit may be set to the correct value. With a nominal gap of 60 mils a coil of this type has an inductance of the order of 0·27 henry/1,000 turns; thus, for the required inductance of 0·045 henry, about 410 turns would be necessary. Actually, the experimental model used had 470 turns of 22 S.W.G., D.S.C. Having decided upon the design of the coil, it is then necessary to select a suitable condenser. A mica dielectric type might have been utilised, and no further experiment done, but this seemed unnecessarily extravagant, so various paper types were examined, commencing with the ordinary, general purpose, P.O. M.C. pattern. These were abandoned, since it was found that their effective resistance was of the same order as that of the coil. The most satisfactory kind finally appeared to be the P.O. M.C., " Y " type, used in radio-interference suppression work, and two of these were used in parallel having capacitances of 2 and 0·25 μF respectively. The complete resonant circuit had a Q of 25-30 when carrying 500 mA A.C. at 500 c.p.s.

In order to obtain maximum output power from amplifiers of this type it is necessary that X/R_o shall lie within certain limits. The value of X/R_o here is 141·6/400, i.e. 0·354: With this value of X/R_o, and with the Q of the circuit equal to 30, conditions closely approach the optimum, and it follows from Fig. **5** of the earlier paper that a working efficiency (η') of 85 per cent. can be obtained. Here, working efficiency is defined as the ratio of the maximum power dissipated in R′ to the power the output valves can dissipate in a purely resistive load connected in their anode circuit. The lowest permissible value for the total circuit resistance R_m is given by

$$R_m = (X/Q^{\frac{1}{2}}) - (X/Q)$$
$$= 40 \text{ ohms (approx.).}$$

Then the output voltage, expressed as a fraction (δ_m) of the no-load voltage, will be,

$$\delta_m = 1 - (1/Q)\sqrt{(R_o^2/X^2) - 1}$$
$$= 0{\cdot}9 \text{ (approx.)}$$

The specification previously referred to requires that the output voltage shall not exceed 6·3 when the current in a non-reactive load is 4 mA ; this corresponds with a fractional regulation of approximately (1 — 10·2/12·6), i.e. 0·81. The specified minimum load resistance is 5·1/0·08, i.e. 64 ohms. Thus the design figures for this amplifier are considerably superior to those specified.

Experimental Results.

The full circuit used was that of Fig. **6**. The first test was performed with a steady 500 c.p.s. input to the amplifier (obtained by connecting the suppressor grid of the A.C./S.2 Pen directly to the cathode), and

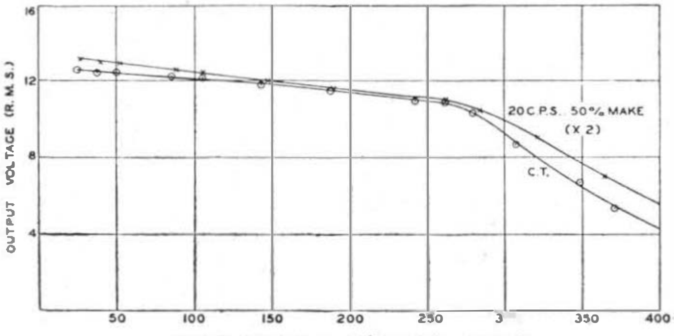

FIG. 9.—REGULATION CHARACTERISTICS OF OUTPUT STAGE.

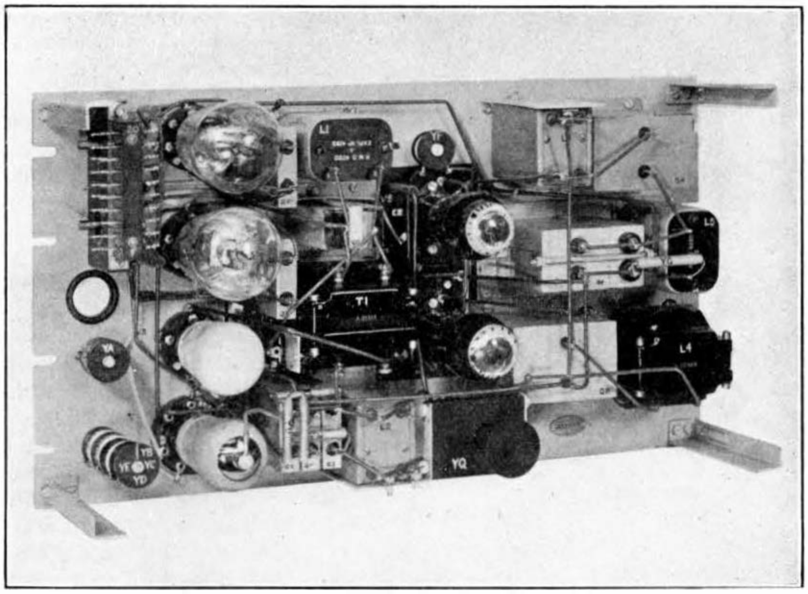

FIG. 10.—THE 500/20 VALVE GENERATOR.

a curve was plotted showing output voltage as a function of output current : this is shown in Fig. **9**, curve C.T. (continuous tone). For reasons to be noted later, the drive voltage was adjusted to yield the required output voltage of 12·6 at 25 mA and not at zero output. From the graph it may be seen that the output voltage with a 40 ohm load resistance (I = 242 mA) is 0·86 of the no-load output. This compares with a calculated value of 0·9. This discrepancy is due partly to the inherent Q of the circuit, which was not quite 30 under working conditions, and partly to the finite anode slope resistance of the tetrode which, in effect, shunts the condenser. It was not felt worth while to pursue the matter further since the regulation obtained at the specified current limit, 160 mA, is 0·92, which compares favourably with the required value 0·81.

It is of interest to note the result of applying a chopped input signal of equal peak value. Such a test was made immediately after the test shown in curve C.T., the only alteration being the connection of the multi-vibrator output to the suppressor grid of the intermittent amplifier. In the previous test the suppressor grid was connected to the cathode. The results are shown by the curve marked 20 i.p.s., 50% "make" (× 2), the readings of voltage and current having been doubled. The curves should superpose ; in fact, the curve taken under chopped conditions is slightly higher. This is due to an effect which will be described later. It was noted that the drive voltage recorded by a rectifier instrument was exactly halved by connecting the chop circuit.

THE 500/20 GENERATOR

The experimental 500/20 generator comprises the two units already described ; the complete circuit is shown in Fig. **6**, and the general layout of the apparatus, which is accommodated on a standard 19 × 10½-inch panel, may be ascertained from Fig. **10**. Some reduction in width might have been achieved by utilising commercial type radio components, but it

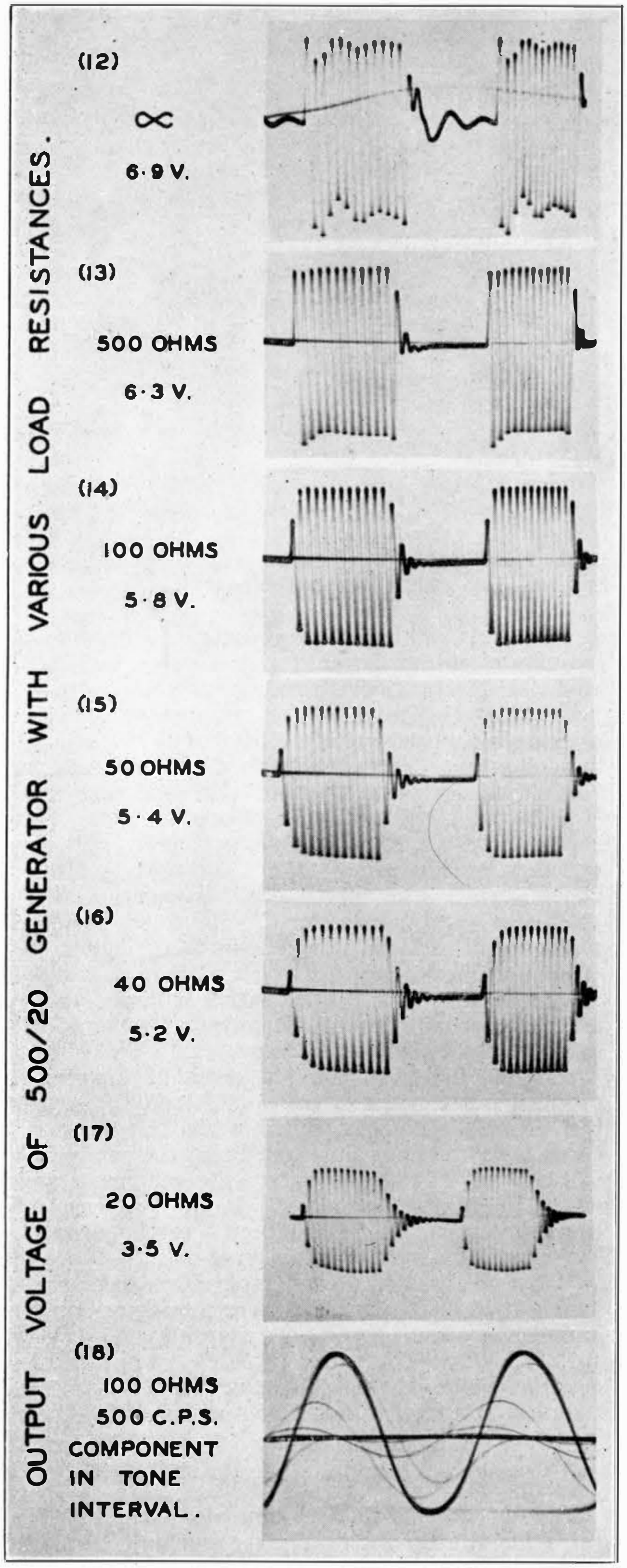

FIG. 11.—OSCILLOGRAMS OF OUTPUT VOLTAGE UNDER VARIOUS LOAD CONDITIONS.

was thought preferable to employ P.O. standard types wherever possible. In the preliminary experiments the 500 ohm resistance shown shunting the load was omitted, and a series of oscillograms of output voltage under various load conditions was taken. This is shown by Fig. **11**; the output voltage figures given are, of course, R.M.S. values. Inspection shows that the waveform of oscillograms 13 to 16 (inclusive) is satisfactory, but those of 12 and 17 are not. In 17 the output is low and the envelope distorted. That the output voltage should be low follows at once from the design data of the preceding section, where it was stipulated that the total output resistance should not be less than 40 ohms. The envelope distortion is of the exponential character which necessarily accompanies the increasing quality of the output resonant circuit; in fact, it does not appear suddenly in 17, but enters progressively in 13 to 17, but is unimportant except in 17. In 12 the no-tone interval exhibits a transient L.F. oscillation; this accounts for the high reading under chopped conditions, noted in an earlier section, and also for the sharp rise in voltage between 500 ohms and infinity recorded by the side of the oscillograms. It was traced to shock excited oscillation in the resonant circuit composed of the 2·25 μF condenser and the 1 henry feed choke, the circuit being completed through the battery. At the comparatively low natural frequency of the circuit the impedance of the 0·045 henry choke is negligible and the output load resistance is effectively connected across it. Oscillogram 13 shows that, as might be expected, with a 500 ohm shunting resistance, the unwanted oscillation is of negligible importance and such was accordingly incorporated internally as a permanent load on the apparatus. Thus oscillogram 16 corresponds with a useful output load of 43·5 ohms, which is still considerably less than the required minimum load resistance of 64 ohms. The waveform in the tone interval is shown by oscillogram 18 and is sensibly sinusoidal.

With the 500 ohm shunting resistance permanently in circuit, regulation characteristics were next taken. These are shown in Fig. 12 for various values of open circuit voltage. The one marked 6·4 is the one relevant to the specification, since it has the value 6·3 at 4 mA. It does not reach the lower specified limit of output voltage until a current of 120 mA is

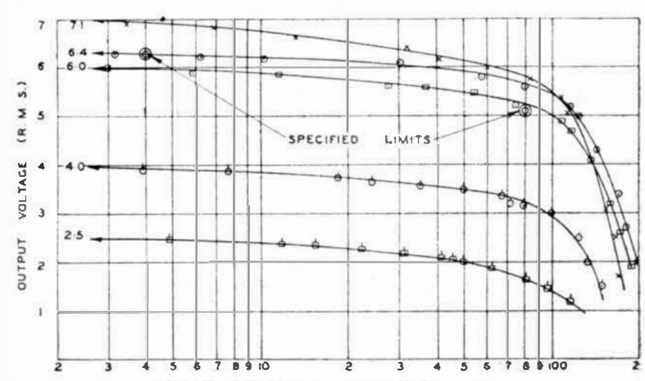

FIG. 12.—REGULATION CHARACTERISTICS OF 500/20 GENERATOR.

reached, whereas the specification calls for 80 mA only. The remainder are included to show that the apparatus is, in fact, used in its most efficient condition, for whereas the 6·4 volt curve does not cross the 2·5, 4 or 6 volt curves at high currents, the 7·1 volt curve does cross them, and this is due to overloading ; 6·4 volts corresponds, therefore, with the highest permissible drive. This point is further illustrated by Fig. **13**, which shows output voltage as a function of drive voltage on open circuit and on full load. The open circuit curve is straight to a value of about 6·4 volts, and thereafter bends over. Since this 6·4 volts is sensibly the oscillating component of the anode voltage of the pentode, the bend is evidently due to overloading in the grid circuit. The full load curve shows a more severe curvature entering at the same grid voltage, and indicates that now overloading is occurring also in the anode circuit. Thus overloading sets in simultaneously in both anode and grid circuits on full load. The normal drive point is shown by the arrow, and it is evident from the figure that, by slight variation about this point, the correct output voltage can be obtained, despite small fluctuations of battery potential.

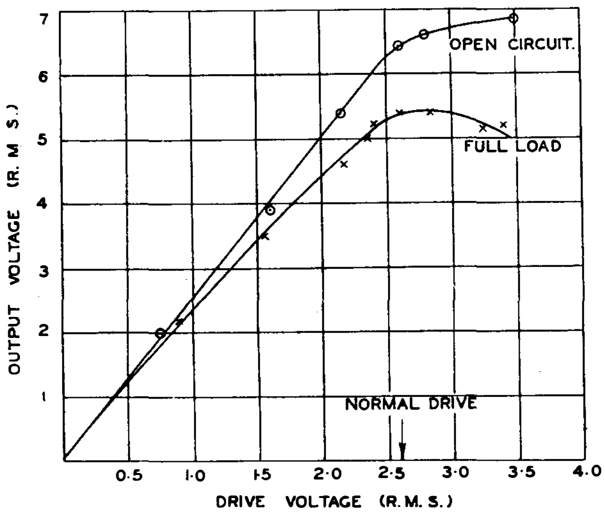

FIG. **13**.—DRIVE CHARACTERISTICS OF 500/20 GENERATOR.

It is desirable in apparatus of this kind that the alternating component of battery current shall be as small as possible. No trouble from this source should arise in the present circuit, for the multi-vibrator valves operate in phase opposition and, if they are balanced, there is no residual 20 c.p.s. component in the battery lead. The space current in the A.C./S.2 Pen alternates between screen and anode at 20 c.p.s., and the total is therefore free of 20 c.p.s. component. Higher frequencies such as 500 c.p.s., and harmonics of the 20 c.p.s., may be excluded by a simple choke-capacitance filter. A system of filament heating suitable for the battery supplies described earlier is shown in Fig. **6**.

Acknowledgement.

The research described in this paper was carried out partly in the Signalling Apparatus Laboratory of the Post Office Engineering Research Station and partly in the Electrotechnics Department of the Victoria University of Manchester. The authors' thanks are due, therefore, both to Captain B. S. Cohen, O.B,E., F.Inst.P., M.I.E.E., and to Professor R. Beattie, D.Sc., for the facilities provided.

TELEGRAPH AND TELEPHONE PLANT IN THE UNITED KINGDOM
TELEPHONES AND WIRE MILEAGES. THE PROPERTY OF, AND MAINTAINED BY
THE POST OFFICE IN EACH REGION AND ENGINEERING DISTRICT AS AT 31st MARCH, 1939.

Number of Telephones	OVERHEAD WIRE MILEAGES					Region or District	UNDERGROUND WIRE MILEAGES					
	Telegraph	Trunk	Junction	Exchange*	Spare		Telegraph	Trunk	Junction‡	Exchange†	Telephone Spares Trunk	Telephone Spares Junction‡
1,177,846	324	502	1,532	57,445	5,627	London Reg.	23,660	318,192	946,212	3,264,651	85,948	278,482
147,238	1,541	1,415	10,960	57,715	12,648	S. Eastern	5,717	138,334	24,370	395,200	55,916	21,410
177,829	1,835	10,311	26,946	116,093	10,451	S. Western	19,835	145,094	15,852	359,927	66,656	20,489
126,270	2,158	8,621	21,849	88,614	21,475	Eastern	6,801	169,782	20,116	262,599	116,504	20,666
146,216	2,387	10,230	18,191	74,528	27,633	N. Midland	9,352	228,696	23,832	299,197	118,032	25,499
162,818	1,306	4,598	15,904	81,572	20,609	S. Midland	10,381	208,014	38,638	414,298	68,904	37,890
85,213	936	4,140	16,632	60,079	11,523	S. Wales	6,035	93,110	18,292	159,720	73,550	17,354
213,797	1,561	9,170	23,636	91,619	18,718	N. Wales	12,237	244,340	105,624	459,593	113,570	38,526
41,813	2,745	6,678	6,718	19,628	1,745	N. Ireland	1,600	15,744	7,998	90,897	25,020	4,878
355,585	1,657	2,912	8,141	75,490	19,625	N.W. Region	16,468	273,920	129,887	977,786	182,700	69,049
303,216	3,963	10,922	21,665	105,124	32,566	N.E. Region	17,395	280,684	75,374	734,345	201,958	50,686
280,863	5,687	22,451	31,694	106,887	28,315	Scot. Region	11,446	233,688	40,609	552,389	151,898	39,682
3,218,704	26,100	91,950	203,868	934,794	210,935	Totals	140,927	2,349,598	1,446,804	7,970,602	1,260,650	624,611
3,164,652	28,987	99,175	207,830	921,317	207,240	Totals as at 31 Dec., 1938	140,624	2,257,212	1,395,629	7,876,026	1,221,908	632,522

* Includes low gauge spare wires, i.e. 40 lb. † Includes all spare wires in Local Underground cables. ‡ Wholly Junction Cables.

Additional Group Modulated Carrier Systems between Stranraer and Belfast

U.D.C. 621.395.443.2

R. J. HALSEY, B.Sc.(Eng)., A.C.G.I., D.I.C., and
F. SCOWEN, B.Sc., A.Inst.P.

The high-frequency cables between Belfast and Stranraer were initially equipped with modified Carrier Systems No. 4 (1 + 3 circuits) and a Carrier System No. 5 (12 circuits). Two additional 12-circuit groups have recently been added by group modulating normal 12-circuit systems. Provision is made for the addition of three further groups on the same basis, thus giving an upper frequency limit of 300 kc/s.

Introduction.

THE cables and the initial installation of carrier equipment between Belfast and Stranraer have been fully described in this JOURNAL[1] so that the present article will be concerned only with the subsequent provision of circuits on the route. The high frequency cables are of balanced pair construction between Stranraer and Port Patrick (7·18 miles) and between Belfast and Donaghadee (18·14 miles); the submarine cables between Port Patrick and Donaghadee are concentric with paragutta dielectric (21·04 and 21·31 nauts.), separate cables being provided for the two directions of transmission. The initial installation consisted of two modified Carrier Systems No. 4[2] (1 + 3 circuits operated on a duplex basis on each cable) and a Carrier System No. 5 (12 circuits) (Fig. **1**). These systems utilise the frequency range up to 60 kc/s.

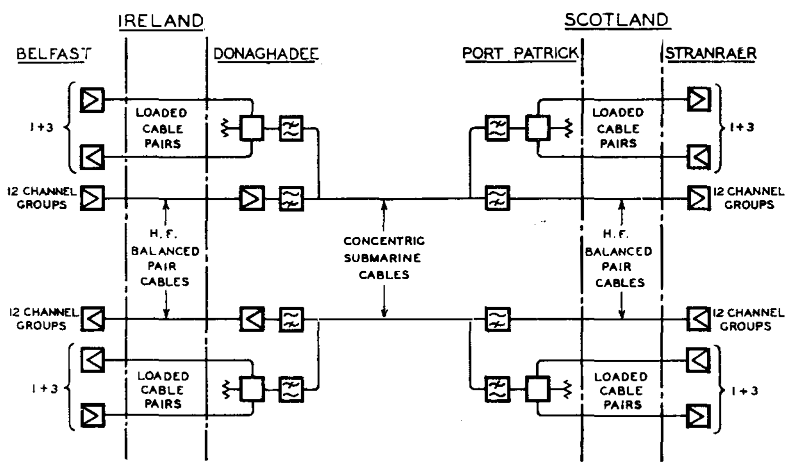

FIG. **1**.—CABLE SYSTEM, BELFAST STRANRAER.

The cables are suitable for transmission of frequencies considerably higher than this and the additions described in the present article form the first part of a larger scheme involving a total of six 12-circuit systems with a maximum frequency of 300 kc/s. Above this range it will be possible to make further extensions at a later date although no provision has been made at present.

The additional groups, i.e., beyond the initial 12-circuit group, are formed by the group modulation of standard 12-circuit systems, these being transmitted in the frequency ranges 60-108, 108-156, 156-204, 204-252 and 252-300 kc/s. The first two of these additional groups have now been provided, the channel modulating equipment being normal 12-channel terminals supplied by Messrs. Standard Telephones and Cables, Ltd. The repeaters, group modulating equipment and group frequency generators were designed and made by the Post Office. Although the principle of group modulation is now of common application[3], the groups to be modulated have previously been chosen so that the ratio of the extreme frequencies is less than 2; this ensures that all second order modulation products fall outside the required frequency band and thereby avoids interference due to intermodulation of the channels in the group modulators and demodulators. The choice of primary groups such as 60-108 or 60-100 kc/s is partly governed by such considerations. In the present equipment the primary group is 12-60 kc/s so that it has been necessary to design group modulators of higher quality than those usually required.

Since the line repeaters transmit the normal 12 channels as well as the modulated groups, their ultimate working range is from 12-300 kc/s, i.e., a ratio of 25 between extreme frequencies.

Repeater Sections.

For the present scheme it has been necessary to install one intermediate repeater station at Donaghadee; for the full scheme a further repeater station will probably be necessary at Port Patrick although this may be avoided by the use of compandor equipment[4] to reduce resistance noise. At 156 kc/s, the highest frequency for the present groups, the cable attenuations are as follows:

Belfast-Donaghadee	32 db.
Donaghadee-Stranraer	52 db.

The necessary constant impedance line equalisers and additional pads give repeater section attenuations of about 60. db.; the requisite equalisation can be readily deduced from curves given in the earlier article. As installed, the overall wideband circuit is equalised flat within about ± 1·5 db.

General Arrangement.

Fig. **2** is a block schematic of the Belfast and Stranraer terminals and Fig. **3** shows the arrangements

[1] *P.O.E.E.J.* Vol. 31, p. 23.
[2] *P.O.E.E.J.* Vol. 29, pp 226 and 294.
[3] See for example *P.O.E.E.J.*, Vol. 30, pp. 206 and 270, and Vol. 31, pp. 51 and 132.
[4] *P.O.E.E.J.* Vol. 32, p. 32.

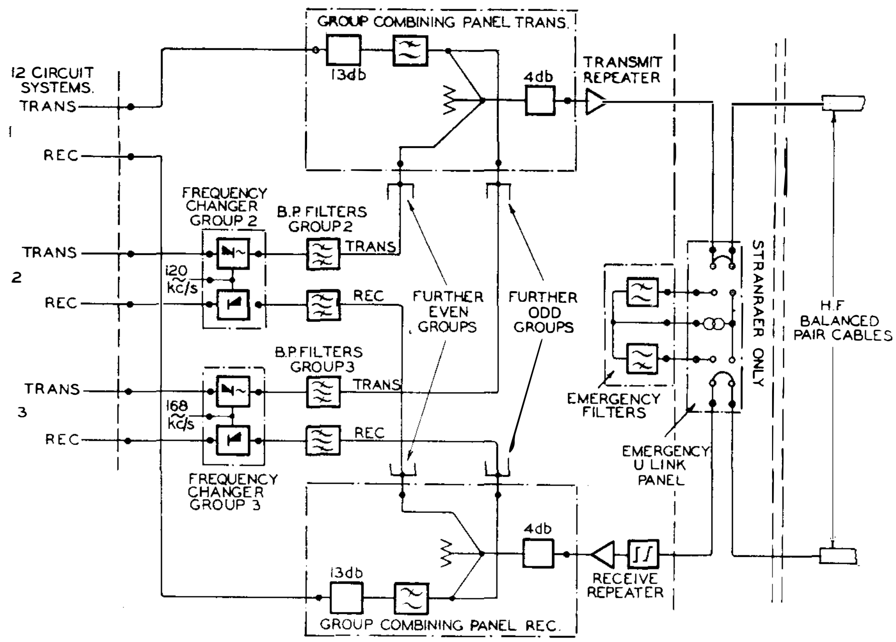

FIG. 2.—TERMINAL EQUIPMENT AT BELFAST AND STRANRAER TERMINAL STATIONS.

at Donaghadee and Port Patrick. The 12-circuit systems are of normal type except that transmitting amplifiers are not fitted on either the normal or modulated groups.

Fig 4 shows the frequency allocation of the channels. Group 1 is transmitted over the cables via the group combining equipment and repeaters, without change of frequency, lower sidebands being transmitted. Group 2 is modulated with a carrier frequency of 120 kc/s and the lower group sideband is filtered out and transmitted via the group combining equipment and repeaters. Group 3 is similarly modulated with a carrier of 168 kc/s and further groups, when added, will be modulated with carrier frequencies of 216, 264 and 312 kc/s. In all the modulated groups the channel sidebands are erect, whereas in the primary group they are inverted.

If one submarine cable is faulty, U-links at Stranraer and Donaghadee are changed over and the Stranraer-Belfast direction of transmission utilises the whole of group 1 and channels 7-11 of group 2, while the Belfast-Stranraer direction utilises channels 1-5 of group 2 and the whole of group 3.

Owing to filter difficulties, only 11 channels of group 2 are at present used, the 60-64 kc/s channel being unworkable. It is hoped to overcome this difficulty at some later date by using crystal group filters for group 2. It will be observed that channel 12 of group 1 and channel 12 of group 2 are lower and upper sidebands of the same virtual carrier frequency[5], i.e., 60 kc/s.

[5]A speech channel, in a carrier telephone system, may be transposed to the frequency band in which it is to be transmitted, by successive stages of modulation. It is possible, and sometimes convenient, to imagine the speech channel as having been transposed, from its original audio range position to its final position in the frequency scale, by one modulation stage only. The imaginary modulating frequency, which would have effected such a single stage transposition is then referred to as the "virtual carrier," and demodulation could be achieved in one stage by the application of this virtual carrier, if desired, instead of by the successive application of demodulating processes.

DETAILS OF EQUIPMENT

Group Frequency Changers.

The frequency changers for groups 2 and 3 are identical and are shown in Fig. 5. They include a modulator, a demodulator and associated pads and filter. "Ring" type modulators are used, with copper oxide rectifiers; it has been found that this arrangement is suitable if the carrier voltage is high and the input level low. Input levels of about − 30 db. are used and this explains why group transmitting amplifiers are not required on the 12-circuit equipments.

The transformers used are much more bulky than is necessary, but later units for similar schemes are more compact, being accommodated on the group filter panels. The low-pass filter attenuates the carrier frequency and the upper sideband of demodulation to avoid overloading the group receiving amplifiers.

Group Carrier Frequency Generators.

The carrier frequencies of 120 and 168 kc/s are generated by crystal-controlled oscillators, the crystals being mounted in temperature-controlled ovens. The oscillators are supplied from one of two mains units and the bays are equipped for the addition of the 216, 264 and 312 kc/s generators. A spare oscillator can be switched to provide any one of the group carrier frequencies. It is hoped to include an article on this equipment in a subsequent issue of this JOURNAL.

Group Filters.

The group band-pass filters are designed to have a flat impedance-frequency characteristic in the pass range and to attenuate the unwanted frequencies by at least 70 db. Low loss inductors and clamped mica condensers are used, each resonant unit being sealed in a copper case after adjustment. "Q" values in excess of 200 have been obtained for all units. The filters have an impedance of 200 Ω, this giving about

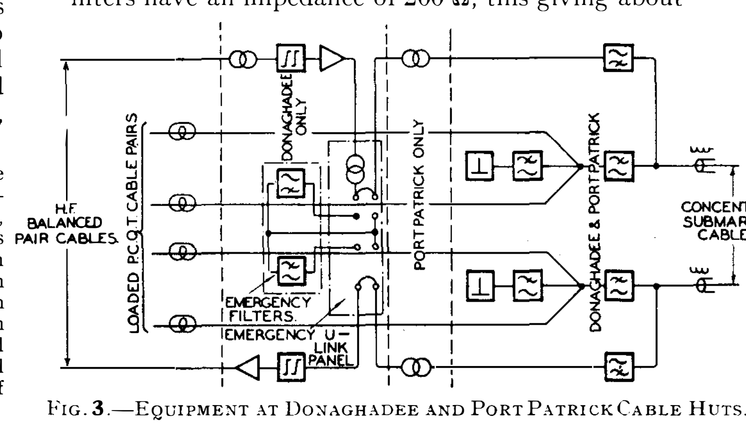

FIG. 3.—EQUIPMENT AT DONAGHADEE AND PORT PATRICK CABLE HUTS.

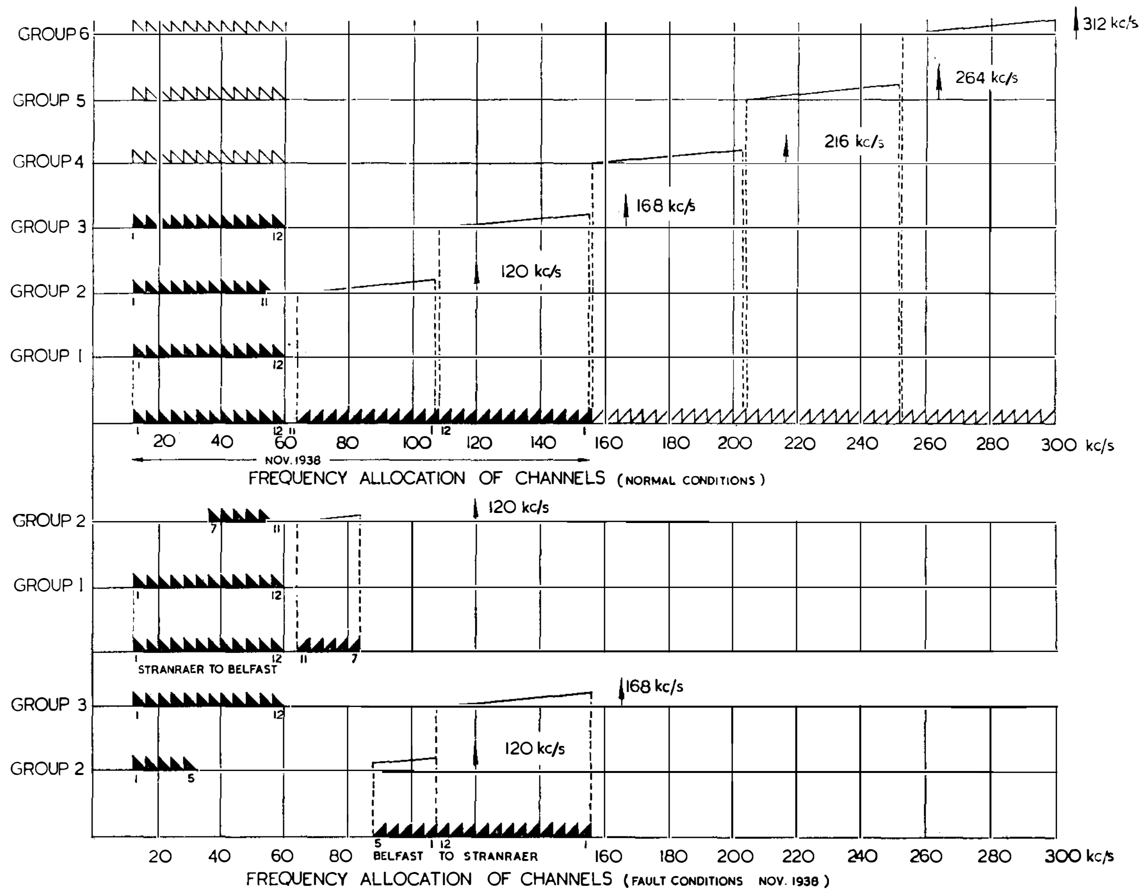

FIG. 4.—FREQUENCY ALLOCATION OF CHANNELS.

the most convenient values of inductance and capacitance. Since the pair cables also have an impedance of about 200 Ω the repeaters may have similar impedances at their input and output terminals.

Figs. **6** and **7** show the pass-band insertion loss of the two group filters. The attenuation of the group filter in the band 60-64 kc/s makes this channel unworkable at present. Fig. **8** shows the circuit of group 3 filter.

Group Combining Units.

Fig. **9** shows the arrangements for combining the groups. Owing to impedance difficulties it is not convenient to connect all the group filters in parallel at their line terminals. The scheme adopted consists of paralleling all the odd numbered group filters and, separately, all the even numbered group filters. The two sets of filters so formed are combined by a differential transformer, i.e., a bridge, so that, with a reasonable balance return loss, each set of filters is protected against impedance variations in the other set. This results in greatly improved group filter characteristics. A small low-pass filter for group 1 is incorporated in the group combining unit; the panel is labelled "filter hybrid panel" in the photograph of the terminal equipment Fig. **10**.

Repeaters.

The line repeaters have fixed gains of 62 db. They are 3-stage amplifiers with a combination of series and parallel feedback between the anode circuit of the output valve and the grid circuit of the input valve, the gain reduction by feedback varying from about 50 to 35 db. in the working range 12-300 kc/s. The input and output impedances of all repeaters are 200 Ω. Since the Donaghadee repeaters are at the junction of the 200 Ω land cables, and the 50 Ω submarine cables, an impedance matching transformer is connected between the output of the Belfast-Stranraer repeater and the sea cable, and a similar transformer is incor-

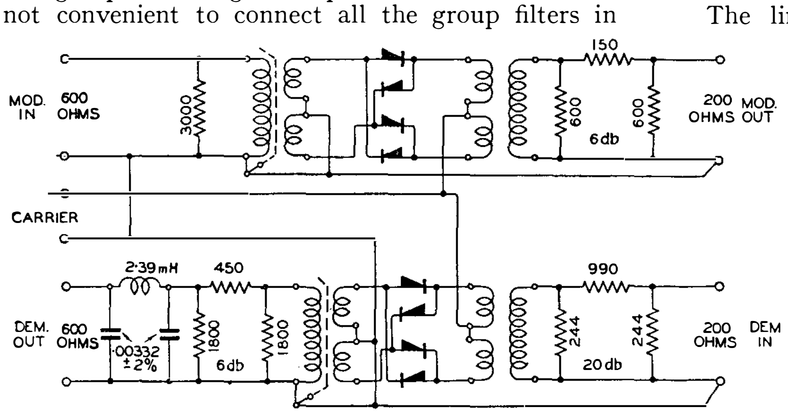

FIG. 5.—GROUP FREQUENCY CHANGER.

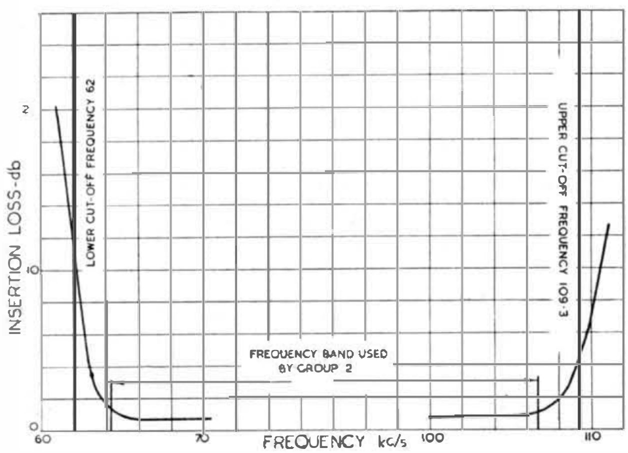

Fig. 6.—Insertion Loss of Group 2 Band-Pass Filter between 200 Ohm Impedances.

porated in the input circuit of the Stranraer-Belfast equaliser, which has a constant impedance of 200 ohms.

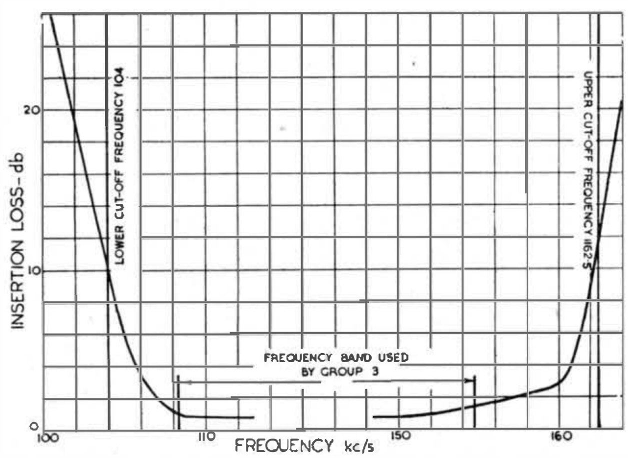

Fig. 7.—Insertion Loss of Group 3 Band-Pass Filter between 200 Ohm Impedances.

Three repeaters, including one spare, are fitted at each station, the power consumption being shown in Table 1.

Table 1

Valve No.	Type	Heater	Anode	
			Volts	Current mA
1, 2	Osram KTZ 41 (Tetrode)	4·0 V 1·5 A	170	7
3	VT114 (Pentode)	4·0 V 2·0 A	240	50

Figs. **11** and **12** show the circuit and photograph of a repeater, the gain-frequency characteristic of which, with and without feedback, is shown in Fig. **13**. Fig. **14** shows typical input and output impedances, expressed as return losses against the nominal

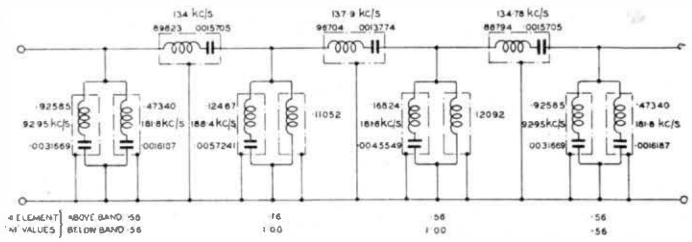

Fig. 8.—Band-Pass Filter, Group 3.

impedance (200 Ω non-reactive). These impedances are not of great importance for the present scheme, but high return losses against the cable impedance are necessary for other schemes, in which similar repeaters are used on multi-pair cables. Where the impedances are important, the upper frequency limit of the repeaters is about 150 kc/s, which will permit three groups to be transmitted.

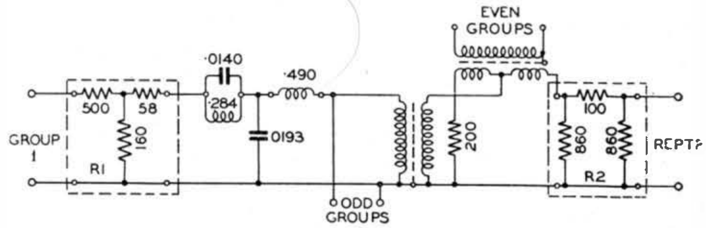

Fig. 9.—Group Combining Panel.

The repeater overloads at about 2·6 W or 34 db. above 1 mW. At 1 W output the total harmonic is at least 55 db. below the fundamental at all working frequencies up to 300 kc/s. At an output level of 5 db. above 1 mW the harmonic is always at least 80 db. below the fundamental.

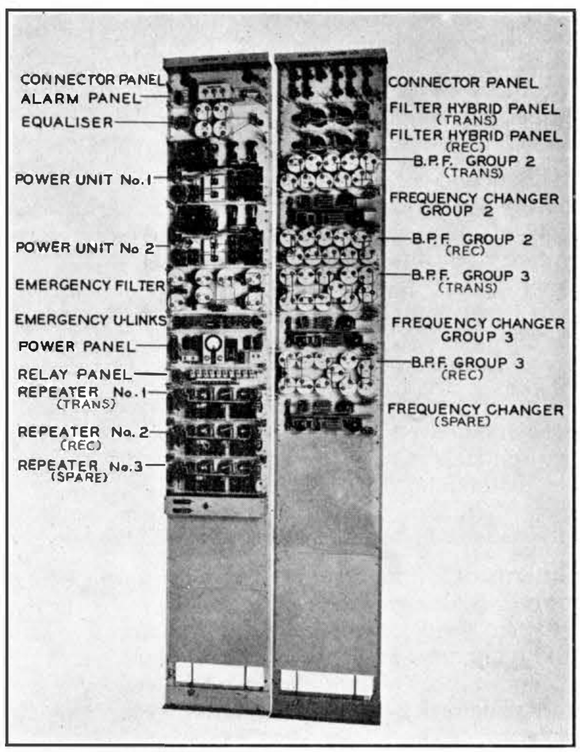

Fig. 10.—Repeater and Frequency Changer Bays at Terminal Station. (Covers Off.)

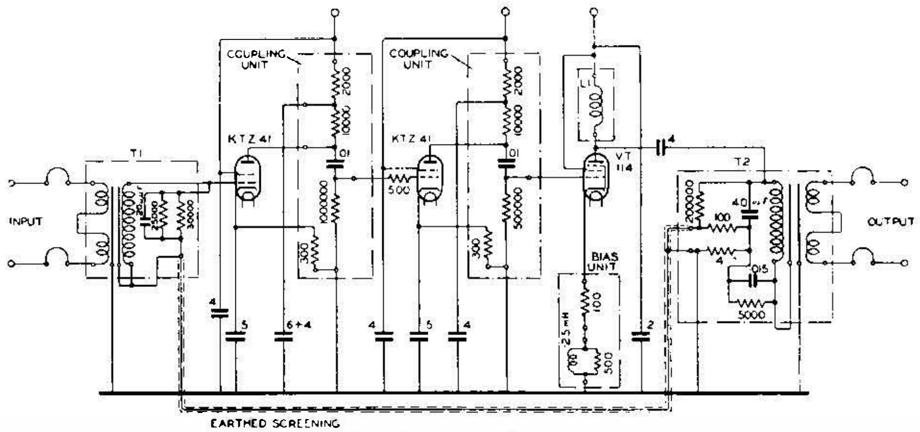

FIG. 11.—LINE REPEATER.

Power Supplies.

The repeaters and group frequency generators are mains-operated (240 volts A.C.). Emergency arrangements include motor generator sets run from the A or B batteries to provide an alternative 50 c/s supply. Two mains units are provided at each station for the repeaters, and two mains units at each terminal station for the group frequency generators. By the use of switching panels, either of the two units can be used to supply the power to the equipment, and facilities are provided so that the anode currents of the valves can be measured.

MEASUREMENTS ON SYSTEM

Each channel was initially lined up at 800 c/s so that, with 1 mW applied to the channel modulators through 4 db. pads (i.e., equivalent of 4-wire terminating set), the relative level at the output of each line repeater was about "zero." Measurements were made at the output terminals of the channel amplifiers and corrected to zero relative level. The measurements show the effect of the group filters on the frequency response of the end channels in each group, and the intermodulation noise due to group frequency changers and repeaters.

Typical Gain/Frequency Characteristics of Channels.

Gain-frequency characteristics of typical channels in the modulated groups are given in Table 2. No group equalisers are fitted to compensate for group filter distortion.

Intermodulation in Group Frequency Changers.

Intermodulation introduced by the group frequency changers is due to modulation products of the form C $\pm$ (ma $\pm$ nb), where C is the carrier frequency, a and b are any two input frequencies and m and n are integers. Since the modulator is followed by a group filter, which passes only the lower group sideband, the terms of the above form which are relevant are only those falling between (C−60) kc/s and (C−12) kc/s i.e., any interference must fall within the same group. Measurements were made at the outputs of the receiving channel amplifiers and the figures obtained for interference on suitably selected channels within the same group are almost entirely due to intermodulation in the group modulator, group demodulator and group receiving amplifier. Speech at reference telephonic power (R.T.P.) was applied to certain channels as disturbance and the disturbed channels were selected so that the intermodulation due to second and third order products was obtained for each group at the ends and the middle of the group. Typical results, for group 3, measured at Stranraer, are given in Table 3.

The Post Office specification for 12-circuit carrier systems requires that, with two speakers at R.T.P., the noise E.M.F., measured with a psophometer, on any other channel, shall not exceed 2·0 mV at a point of zero relative level.

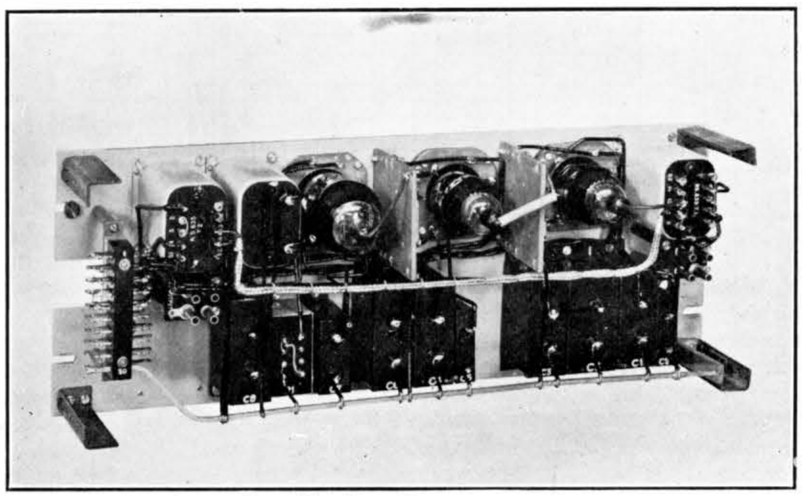

FIG. 12.—LINE REPEATER.

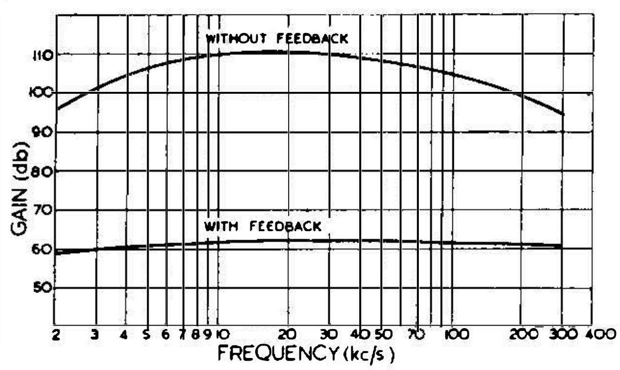

FIG. 13.—GAIN/FREQUENCY CHARACTERISTIC OF LINE REPEATER.

TABLE 2

Frequency c/s	Group 2				Group 3			
	Ch. 1	Ch. 2	Ch. 10	Ch. 11	Ch. 1	Ch. 2	Ch. 11	Ch. 12
300	− 0·2	+ 0·2	− 1·7	− 1·7	0	0	− 0·9	− 2·0
500	0	+ 0·5	− 0·2	+ 0·1	+ 0·3	+ 0·1	− 0·2	− 0·4
800	0	0	0	0	0	0	0	0
1,400	+ 0·5	+ 0·2	+ 0·1	+ 0·2	− 0·1	0	0	+ 0·1
2,000	+ 0·3	+ 0·1	+ 0·2	+ 0·7	0	+ 0·1	+ 0·3	+ 0·6
2,400	+ 0·2	+ 0·2	+ 0·5	+ 0·8	− 0·2	+ 0·1	+ 0·3	+ 0·3
2,600	+ 0·3	+ 0·3	+ 0·3	+ 0·7	+ 0·1	0	0	+ 0·1

TABLE 3.

Disturb on Channel	Receive on Channel	Noise at Stranraer	
		Noise E.M.F.	S/N ratio
		mV	db
1	5	0·5	76
1	9	0·4	78
2	11	0·28	81
4	11	0·3	80
7 and 11	1	0·35	79
2 and 11	1	0·4	78

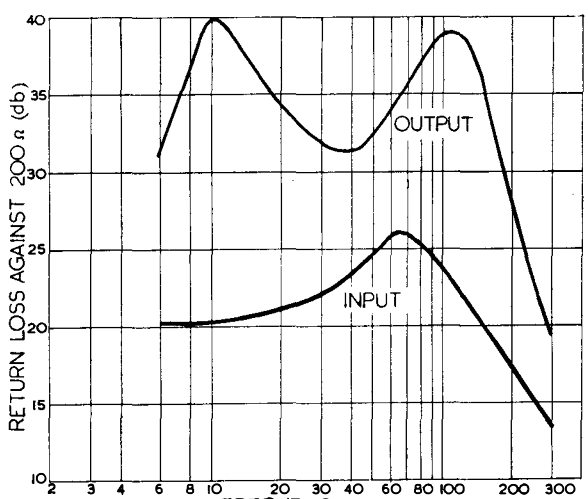

FIG. 14.—INPUT AND OUTPUT IMPEDANCES.

Intermodulation in Line Repeaters.

Intermodulation in line repeaters is caused by the generation of components of the form (ma ± nb) where a and b are signal frequencies passing through the repeaters and m and n are integers. The combinations tested are those expected, from the above considerations, to give the worst interference, and the results in Table 4 are due to the three line repeaters.

Interference between Adjacent Channels in Different Groups.

The crosstalk attenuation from the end channel of one group to the adjacent end channel of the next group is always greater than 80 db.

TABLE 4

Disturb on		Receive on		Noise at Stranraer	
Group	Chan.	Group	Chan.	Noise E.M.F.	S/N ratio
				mV	db.
1	1	1	5	0·45	77
1	1	1	9	0·4	78
2	8	3	1	0·4	78
1	10	2	2	0·3	80
1	10	3	1	0·35	79
1	7	2	10	0·25	82
1	7	2	1	0·4	78
3	1 & 5	1	1	0·85	71
2 3	10 1 }	2	1	0·85	71

Conclusions.

The provision of two additional 12-circuit groups between Belfast and Stranraer has been carried out in a satisfactory manner by the group modulation of normal 12-circuit systems. The repeaters now carry three groups in the frequency ranges 12-60, 60-108 and 108-156 kc/s and after the addition of another repeater at Port Patrick further groups in the ranges 156-204, 204-252 and 252-300 kc/s may be provided when required. The cables now normally carry 43 circuits, with emergency arrangements giving 21 circuits when one cable is faulty.

The Nevin-Dublin Carrier System for Telephony and V.F. Telegraphs

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U.D.C. 621.315.212 621.315.213 621.315.285 621.394.44 621.395.443.2

Additional circuits to Dublin have recently been provided by carrier working over two new concentric submarine cables. The authors give details of the equipment and cables.

Introduction.

TELEGRAPHIC communication with Eire via North Wales commenced in 1871, after the laying of the Trecastell-Howth 7-core cable, which carried the following public circuits :—

London-Dublin, London-Cork, Manchester-Dublin, and Liverpool-Dublin. It also carried private wire circuits between :—

The Irish Office and Dublin Castle, Direct United States Cable Co. and Ballinskelligs, and the Anglo-American Cable Co. and Valentia.

The last of these circuits was relayed at Dublin, but the remainder were relayed at the Llanfair repeater station, Anglesey. This station was situated about 15 miles from the cable hut and was the link between the main aerial route and the submarine cable. The accommodation consisted of a small room over the village post office, and the power supply was obtained from primary batteries in an outhouse.

Considerable interest was taken in this station by Sir William Preece, the Engineer-in-Chief of that time, who visited the station on several occasions and required daily reports on the working of the circuits to be sent direct to Headquarters. One of the items to be particularly reported was the first appearance of snow on the mountains.

After the introduction of the sixpenny telegram the Abergeirch-Newcastle 4-core cable was laid from Nevin (Caernarvon) in 1886 and the Nevin repeater station was opened. Further development took place via Nevin, and the Abergeirch-Newcastle Nos. 2 and 3 cables were laid in 1898 and 1892 respectively, followed by another 4-core cable between Trecastell and Howth in 1902 when the repeater station at Llanfair was moved from the Post Office to other premises. The Abergeirch-Newcastle No. 3 cable was abandoned in 1935.

The telegraph circuits were mainly Wheatstone duplex, working bridge-duplex on the cable side and differential on the inland side. High speed Wheatstone simplex working was also used on the London-Dublin news circuits, the repeaters being of the standard duplex-simplex type. Fig. **1** shows the repeaters at Nevin.

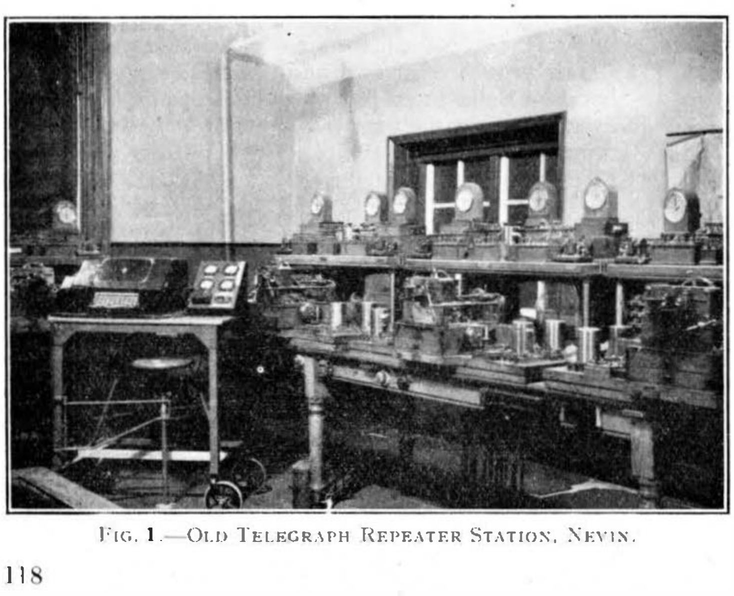
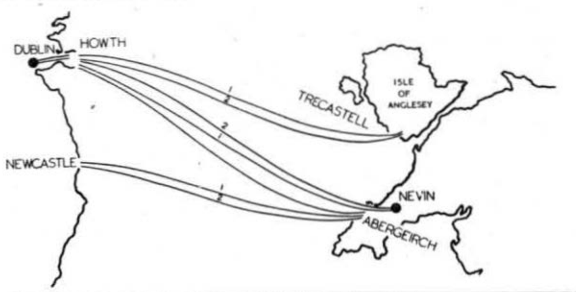


Fig. 1.—Old Telegraph Repeater Station, Nevin.



Route	Cable No.	Date of laying	No. of cores	Nominal conductor Weight lbs. per Naut.	Nominal Dielectric Weight lbs. per Naut.	Length Nauts.	Remarks
Nevin-Howth	1	1937	1	508	690	62·59	Paragutta dielectric, concentric type
Nevin-Howth	2	1938	1	508	690	63·98	Paragutta dielectric, concentric type

Fig. 2.—Submarine Cables between Great Britain and Eire.

The long aerial lines passed over the mountainous district of mid-Wales to Nevin and along the North Wales coast to Llanfair. As a result the working of the circuits was often precarious owing to the current leakage during wet weather or following a gale which had deposited a coating of salt on the insulators of the coastal route. Storms did considerable damage to the exposed sections of the routes and following the snowstorm in February, 1937, which brought down a large section of the Nevin route, it was decided not to repair it.

The factors governing this decision were that in May, 1936, Llanfair repeater station had been superseded by one at Bangor, where an 18-channel V.F. telegraph system was terminated carrying eleven of the existing Irish circuits routed via North Wales. Also it had been decided to lay two concentric, paragutta dielectric cables from Nevin to Howth, the equipment of which forms the subject of this article. One cable is used for each direction of transmission and they are equipped to give sixteen 4-wire telephone circuits, one of which is used for an 18-channel V.F. telegraph system between London and Dublin. The two telegraph repeater stations which have existed in North Wales, one for 68 years and the other for 53 years, through which the main telegraph circuits and two 2-wire telephone circuits to Eire passed, have now been closed.

Fig. 2 shows the existing cables between Great Britain and Eire. Of the five older cables, only one—the Abergeirch Howth—has been used for telephony, two 2-wire circuits being obtained, one Dublin-London and one Dublin-Liverpool ; the other cables have been used for D.C. telegraph circuits. Prior to the installation of the new cables there were two other telephone circuits to Dublin, one from Liverpool and one from London (routed via Belfast), making a total of four circuits between Dublin and England.

Concentric Cables

Design

The same design has been used for these paragutta-dielectric cables as for those previously laid[1]. Fig. 3 shows to scale the cross section of the main submarine

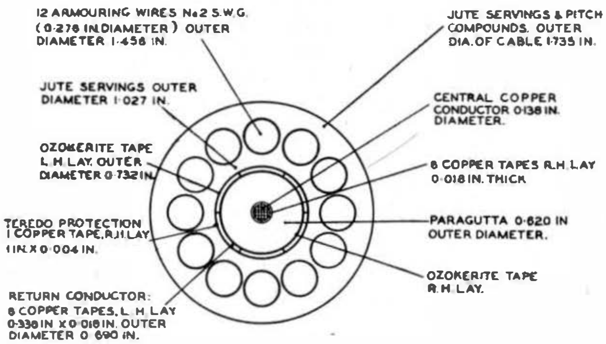


Fig. 3.—Cross-Section of Submarine Cable.

portion of the cable ; the solid, central copper conductor is surrounded successively by six copper tapes, a solid paragutta dielectric, fabric tape, six copper tapes which comprise the outer concentric conductor, fabric tape, jute and wire armouring. The conductor weights are given in Fig. 2.

The shore ends (about 0·3 naut.) are lead covered to protect the paragutta from light and air which would reduce its life. An improvement in the ageing properties is also expected to result from the addition to the paragutta of an anti-oxidant. The land section (1·20 nauts.) between the cable hut at Abergeirch and Morfa Nevin repeater station is lead covered ; part of this section is telconax sheathed (to protect it against corrosive soil) and drawn into ducts, and part is steel tape armoured and laid direct in the ground.

Laying Operations.

In North Wales the cables land at Abergeirch where there is a cable hut just above high water mark. This is not

Fig. 4.—Carrier Repeater Station at Howth.

a suitable place for a repeater station and the cables are continued overland to Morfa Nevin new repeater station. At Howth in Eire the cables are terminated in a building about quarter of a mile from the beach. An old Martello tower has been used for this cable termination and provides a very convenient intermediate repeater station, accommodating equipment and power plant. Fig. 4 shows the tower with the island Ireland's Eye in the background. One cable was laid in September, 1937, and carried four circuits on temporary equipment until the second cable was laid in August 1938. Fig. 5 shows a shore end being floated in on barrels from the C. S. Faraday (Messrs. Siemens Bros. & Co., Ltd.) at Abergeirch. This method was possible for the 1937 cable as there is sufficient depth of water for the ship to come in fairly close to the beach (within about 700 yards), and a direct pull on the cable could be obtained. An

Fig. 5.—Landing Cable Direct from C.S. Faraday at Abergeirch.

[1] *P.O.E.E.J.* Vol. 30, p. 222. Vol. 31, p. 23.

auxiliary craft had to be used to land the shore end of the 1938 cable at Abergeirch because a direct pull could not be obtained; the cable lands at an angle with the 1937 cable to give the adequate separation to avoid cross-talk between cables and to facilitate repair operations. The cables were hauled to the cable hut at Abergeirch by horse and man power. The shore end having been laid in North Wales the cable ship paid out about 32 nauts on a bouyed course at an average speed of about 5 knots. The shore end at Howth was then laid and about 30 nauts of cable paid out to meet the eastern section of cable and the two ends were then spliced. Including delays due to gales and laying and recovery of the buoys marking the route, the laying of one cable occupied eight days. Both cables were electrically satisfactory after laying, and, after the 30 days' contractor's maintenance period, were therefore accepted by the Post Office.

Electrical and Mechanical Characteristics.

The following figures refer to the 1937 (No. 1) and 1938 (No. 2) (S. & N. respectively) Nevin-Howth paragutta dielectric cables after laying.

	1937 No. 1 Cable	1938 No. 2 Cable
Total length (naut. miles) from Nevin to Howth	62·59*	63·98
Length of land section from Nevin to Abergeirch (naut. miles) ..	1·20	1·20
Overall diameter of submarine portion (inches)	1·70	1·70
Overall diameter of lead-sheathed shore end (inches)	1·80	1·80
Overall diameter of steel tape sheathed land section (inches) ..	1·24	1·24
Insulation resistance at 100 V after electrification for one minute (megohms per naut.)	80,000	71,000
Conductor resistance at 60° F. (ohms per naut.)	2·254	2·260
Actual central conductor weight (lbs. per naut.)	513·5	513·1
Actual outer conductor weight (lbs. per naut.)	852	852
Average capacitance at 60° F. (microfarad per naut.)	0·200	0·201
Attenuation (db. per naut. at 10 kc/s)	0·45	0·45
Attenuation (db. per naut. at 60 kc/s and 57·5° F.)	1·08	1·08
Worst singing point from smooth mean curve (db. in range 0·3 to 16 kc/s)	52·0	54·7
Do. (db. in range 16·0 to 70 kc/s)	44·0	41·0
Near-end cross-talk between cables at Howth (db. in range above 10 kc/s)	>126	
Do. (db. in range above 6·0 kc/s)	>106	

* 62.119 nauts. before the repair of September, 1938.

Fig. 6 shows the impedance-frequency characteristics (actually they are resistance values as measured by a parallel resonance bridge) for both ends of the 1938 cable; the smooth curve gives the values on a smaller scale from 5 down to 0·6 kc/s. The singing points obtained from these curves are given above. In order that the cable should be suitable for duplex or 2-wire working if required, the deviations of the impedance-frequency characteristics from the smooth mean curve were specified as minimum singing points of 43·0 db. from 0·3 to 12·0 kc/s and 46·0 db. from 12·0 to 16·0 kc/s. This would allow a minimum margin of 8 db. between the cable attenuation and the singing point and so would enable 2-wire balances to be constructed with a sufficient stability margin. As these limits have been easily met, as shown by the figures above, and as the attenuations of the cables at 16 kc/s are 34·5 and 35·2 db., there is actually a minimum margin between singing point and attenuation of 52·0−34·5=17·5 db. on the 1937 cable, and of 54·7−35·2=19·5 db. on the 1938 cable. Hence the cables are suitable for duplex working up to 16 kc/s at least.

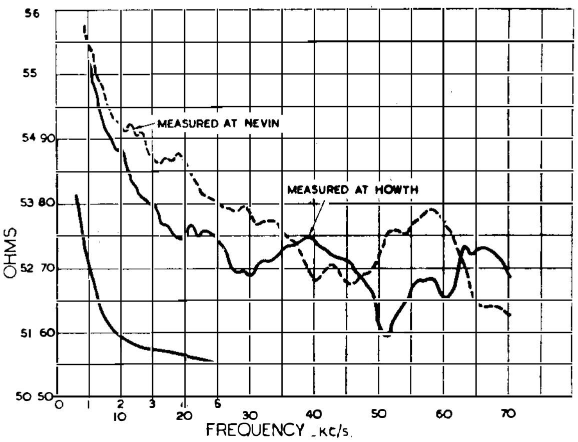


Fig. 6.—Impedance Characteristics of the 1938 Nevin-Howth Submarine Cable.

Fig. 7 gives the attenuation-frequency characteristic of the 1938 cable and shows the amount due to leakance losses. The values for the 1937 cable are very similar.

Howth-Dublin Cables.

Nevin repeater station is the carrier equipment terminal in Great Britain, and circuits are extended thence on an audio basis by 44 mH loaded pairs to Liverpool and London. In Eire the submarine cable terminal is at Howth, which is an intermediate repeater station. The extension to Dublin is by two lead-covered A.S.P.C.Q.T. cables laid (in duct) specially for the purpose. One cable has seven quads and the other three quads, and each cable carries circuits in one direction of transmission only. The allocations of the cable pairs with the directions of transmission are as follows, Nevin being considered as the " Up " station :—

Cable " A."

7 Quads, 40-lb. Conductors.

Pair 1. I.R. tests.
Pair 2. Circuits above 60 kc/s, D-U.
Pair 3. 12 circuit carrier, D-U.

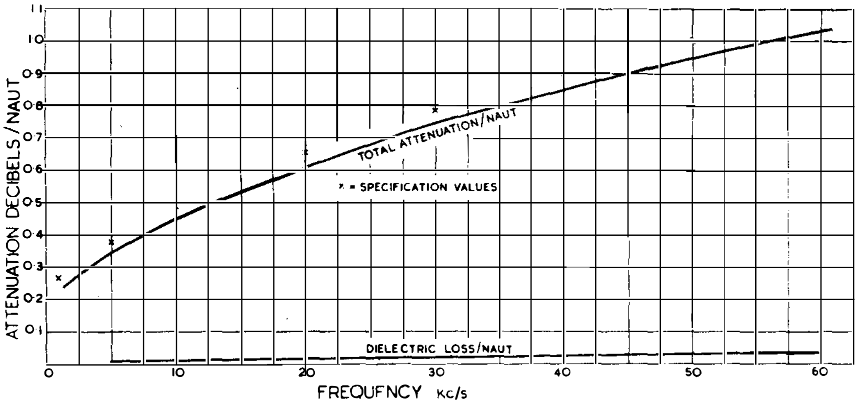


Fig. 7.—Attenuation Characteristic and Dielectric Loss of Paragutta Dielectric Cable.

Pair 4. 1 + 4 circuits, D-U.
Pair 5. Test line amplifier.
Pair 6. Urgent alarm.
Pair 7. Spare.
Pair 8. Spare.
Pair 9. Trecastell-Howth circuit, D-U.
Pair 10. Trecastell-Howth circuit, U-D.
Pair 11. Speaker circuit.
Pair 12. Test alarm.
Pair 13. Spare.
Pair 14. Spare.

Cable "B"

3 Quads, 40-lb. Conductors.

Pair 1. I.R. tests.
Pair 2. Circuits above 60 kc/s, U-D.
Pair 3. 12 circuit carrier, U-D.
Pair 4. 1 + 4 circuits, U-D.
Pair 5. Test line amplifier.
Pair 6. Mains failure alarm.

Other details of the cables are as follows :—

Length (miles)	9·516
Attenuation per mile at 16 kc/s (decibels)	1·79
Attenuation per mile at 60 kc/s (decibels)	3·31
Average impedance at 30 kc/s (ohms)	125·9/9° 4′
Average impedance at 60 kc/s (ohms)	124·4/6° 52′
Average impedance at 160 kc/s (ohms)	114·5/5° 42′
Average near-end cross-talk within cable at 60 kc/s (decibels)	78
Do. at 160 kc/s (decibels)	72
Average distant-end cross-talk within cables at 60 kc/s (decibels)	79
Do. at 160 kc/s (decibels)	71
Cross-talk between pairs in different cables at 60 kc/s (decibels). Average	126
Worst	110

Equipment and Utilisation of the Frequency Band

The lower portion of the frequency spectrum from 0·3 to 16·0 kc/s is used by 1 + 4 type carrier equipment[2] (P.O. Carrier System No. 4)[3] with simplex working, i.e., with "go" and "return" channels in separate cables. For the four carrier circuits, lower side bands of 6·0, 9·2, 12·5 and 16·0 kc/s are transmitted.

The range 16 to 60 kc/s is used by 12-circuit carrier equipment[4] (P.O. Carrier System No. 5). The circuit normally provided by this equipment in the range 12 to 16 kc/s is omitted since this frequency space is occupied by the 1 + 4 type equipment ; hence 11 circuits are provided giving a total of 16. Lower side band transmission is employed, the carrier frequencies being 20, 24, etc., to 60 kc/s. As with the 1 + 4 equipment, "go" and "return" channels are in separate cables ; all 16 circuits are therefore 4-wire throughout from Nevin to Dublin.

The carrier frequency generating equipment now in service has a frequency stability of 3 parts in 10^5 ; in order to provide adequate stability for V.F. telegraph channels, the master oscillators will shortly be replaced by others having a stability of 1 part in 10^5. This stability will be satisfactory when additional circuits at higher frequencies are provided.

Fig. 8 is a simplified block schematic diagram showing cables and equipment at Howth and Dublin : the equipment at Nevin is similar to that at Dublin except that at Nevin the circuits are extended 4-wire to Liverpool and London and the equipment for the Welsh end of the 4-core cable is at Trecastell, Anglesey. Equalisers, line transformers, U links and other details are omitted from the figure. A 500/20 c/s valve oscillator is installed at Nevin for ringing Dublin during maintenance testing. It will be seen that at Howth the circuits on the two types of equipment are separated by a high-pass and low-pass pair of system filters. These are of 52 ohms impedance and unbalanced on the submarine cable side and of 600 ohms impedance and balanced on the equipment side. Amplification is provided in both directions of transmission by a 36A repeater (a spare being provided) for the 1 + 4 equipment, and by line amplifiers (with one spare and two in service) on 12-circuit carrier equipment at both Howth and Dublin. At Dublin halves of normal single stage repeaters (Repeater 26A) are used for amplification on the audio-frequency side of the 1 + 4 equipment, in the receive direction only, on the four carrier circuits. The audio circuit passes via the V.F. telegraph change-over U link panel to the voice frequency telegraph equipment. The 15 carrier circuits pass, on the audio side, via an emergency change-over U link panel (which enables 7 circuits to be worked if one cable fails) to the 2-wire-4-wire terminations and thence to the signalling units (Units, Signalling, No. 3) for conversion from 17 c/s to 500/20 c/s and vice versa.

Fig. 9 is a photograph of the cable termination and equipment bays at Nevin new repeater station.

[2] *P.O.E.E.J.*, Vol. 29, pp. 226 and 294.
[3] *P.O.E.E.J.*, Vol. 31, p. 23.
[4] *I.P.O.E.E.* Printed Paper, No. 167.

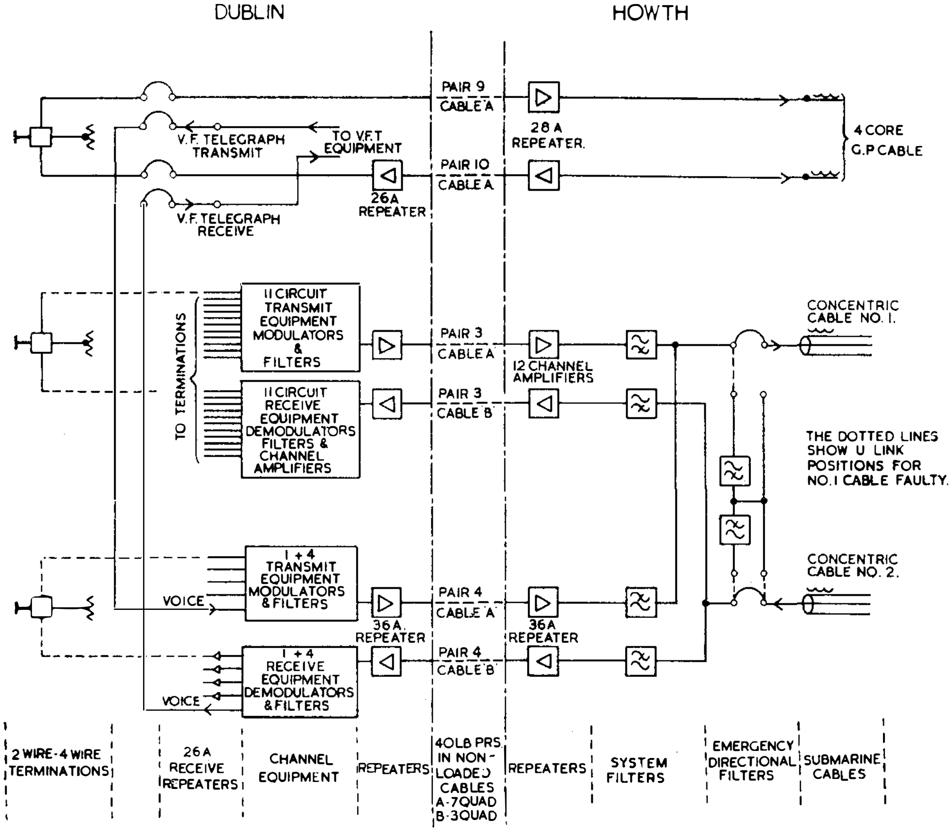


Fig. 8.—Schematic Diagram of Initial 16 Circuits and V.F. Telegraph Reserve Circuits.

Howth submarine cable; this circuit is routed differently in England from the other circuits. As a second reserve in the event of the simultaneous failure of the first reserve circuit and also of one of the concentric submarine cables, the V.F. telegraph circuit is provided on one concentric cable by using the audio frequency band for one direction and the band from 32 to 36 kc/s for the other direction.

The circuits were transferred from the telegraph cable routes to the V.F. system gradually, commencing with four to clear the Trecastell-Howth cable for test as the V.F. reserve. The last of the public circuits was transferred on March 27th, 1939, thus allowing the telegraph repeater stations in North Wales to be closed after a useful service of 68 and 53 years.

V.F. Telegraph Channels.

The 18-channel V.F. telegraph system is routed over the audio circuit of the two cables (TSX-DN 10), the London "go" being on the No. 2 cable and the "return" on the No. 1 cable. Channel tests were made and the following examples indicate the distortion on signals received at the London end.

Test	Channel			
	1	6	12	18
	Percentage Distortion			
Reversals at 66 bauds	12	8	10	8
Reversals at 33 bauds	6	2	6	2
Series of "5 Mark+1 space" signals	6	12	2	4
Series of "1 Mark+5 space" signals	15	15	16	12
"Paris" in Morse Code	10	8	10	4
"Paris" in inverted Morse Code	10	8	10	5

Tests were also made to ensure that the channels were satisfactory for interference and at normal line level the average was about 30 db. with the voltage limiters disconnected at Dublin and Nevin. With the limiters in circuit and the level increased to + 10 db. the interference was found to be 1½ to 2 db. worse. As this made no appreciable difference it was decided to work the system with the limiters in circuit.

Upon a failure of the V.F. telegraph circuit the normal telegraph change-over at London and Dublin is made by U links to put the circuit on the Trecastell-

The Trecastell-Howth Circuit Equipment.

The Trecastell-Howth 4-core cable has been converted from D.C. telegraph to 4-wire telephone working to serve as a V.F. telegraph reserve circuit. The installation at Trecastell includes a working repeater with a nominal gain of 50 db. (Repeater 28A) and a spare, and a submarine cable equaliser on the receive pair; the high gain is necessary due to the length of the submarine cable (64.4 nauts.). The actual maximum gain is about 53 db. and the frequency response of the repeaters is substantially constant from about 200 to 6,000 c/s. A 500/20 c/s valve oscillator has been provided at Trecastell in order to enable Trecastell to call Dublin for testing purposes. At Howth the equipment consists of a 28A Repeater and a spare, and equalisers for the submarine cable and for the Dublin-Howth cable. The nominal output level to the submarine cable is + 10 db. and towards Dublin is zero db. referred to 1 mW in 600 Ω. At Dublin a single stage 4-wire repeater (Repeater No. 26A) is used on the receiving side only, since the loss between Dublin and Howth (including the equaliser) is only 14 db. at 800 c/s. The other half of the 4-wire repeater serves as a spare. The circuit then passes via the V.F. telegraph change-over U links to the termination and signalling unit.

In the event of the failure of one of the concentric submarine cables the U links at Howth (Fig. 9) are changed to the positions shown dotted to bring into circuit the high-pass and low-pass emergency direc-

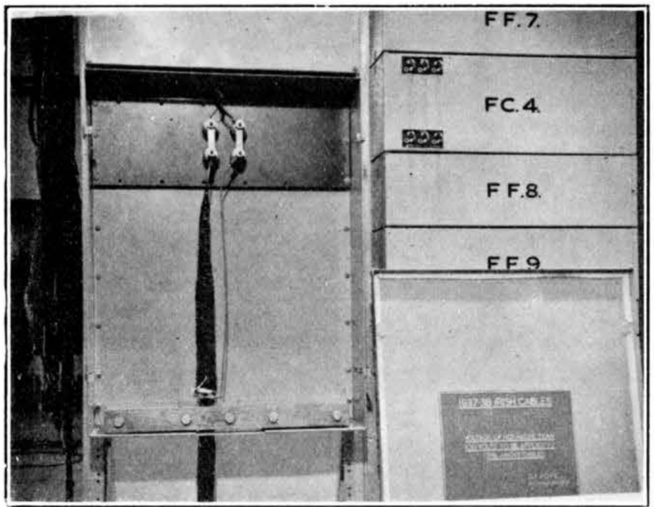


FIG. 9.—CABLE TERMINATION BAY.

tional filters ; the U links on the emergency change-over panel at Dublin and Nevin (on the audio-frequency side of the channel equipment) are also changed to the emergency position. The emergency filters divide the frequency band into two parts, one being used for each direction of transmission ; the range up to 24 kc/s is used for one direction and the range 32 to 60 kc/s for the opposite direction, thus giving seven circuits.

Manufacturers.

The paragutta dielectric submarine cables were manufactured by Messrs. Submarine Cables, Ltd., and the Dublin-Howth cables by Messrs. Pirelli General Cables, Ltd. Messrs. Siemens Brothers & Co., Ltd., provided the 1 + 4 type carrier equipment and Messrs. General Electric Co., Ltd., provided the 12-circuit carrier and audio-frequency equipment and carried out the equipment installation. The V.F. telegraph equipment was manufactured and installed by Messrs. Standard Telephones & Cables, Ltd. The system and directional filters, being special items, were designed and produced by the Research Branch of the P.O. Engineering Department.

Circuit Performance.

All the equipment and circuits were tested and lined up jointly by the Post Office and the manufacturers' representatives, and were found in general to conform to the relative specifications. Satisfactory transmission is provided from 300 c/s to 2,800 c/s on the 12-circuit carrier equipment and to 2,700 c/s on the 1 + 4 carrier equipment.

The telephone circuits were brought into service, using the permanent equipment, during November, 1938.

Future Developments.

Although the present system now in service provides a very large increase in the number of circuits, consideration is being given to the question of exploiting the cables to their maximum economic limit by the provision of additional circuits which will be required shortly. The next stage will probably be the installation of an additional 12-circuit carrier terminal equipment at Dublin and Nevin ; the frequency band will be translated by group modulation from the range 12 to 60 kc/s to the range 64 to 112 kc/s for transmission to line. (Similar systems are already in operation on the Belfast-Stranraer[5] and Aldeburgh-Domburg routes.) The circuits on the existing equipment and the second group of circuits will be separated at the submarine cable terminals by high-pass and low-pass system filters. As the submarine cable attenuation at 112 kc/s is 94 db., a transmitting level of about + 20 db. will be used, giving a receive level of about −80 db. (allowing 6 db. for filter and equaliser losses) which is about 59 db. above the level of thermal agitation noise. If a third group of 12 circuits is added, transmitting in the range 112 to 160 kc/s, then compandors[6] will be required in order to give a satisfactory signal-to-noise ratio.

The authors are indebted to Messrs. Siemens Bros. & Co., Ltd., for certain of the photographs.

[5] *P.O.E.E.J.*, Vol. 31, p. 23, and Vol. 32, p. 112.
[6] *P.O.E.E.J.*, Vol. 32, p. 32.

The New Kingston (London) Exchange

C. H. HARTWELL

U.D.C. 621.395.34 : 621.395.722

Kingston automatic exchange is one of the first London exchanges of the recently standardised 2,000 type equipment to be brought into service, and the author surveys the equipment provided and the facilities afforded.

FIG. 1.—KINGSTON EXCHANGE BUILDING.

Introduction.

ON Wednesday, May 17th, at 1.30 p.m., 5,700 subscribers' lines at Kingston-upon-Thames were transferred to automatic working, together with 776 outgoing junctions and 556 incoming junctions.

This exchange is the 113th automatic exchange opened in the London Director Area. There remain on the programme for the automatisation of London a further 48 exchanges to be opened, so that this immense task is more than two-thirds finished.

Kingston opened with only four exchange faults, and 0·86 per cent. failures on subscribers' lines.

The replaced manual exchange consisted of the following C.B. No. 1 type positions :

38 "A."
2 Toll control.
5 Order wire junction.
5 Coder call indicator.
2 Testing telephonist.
and 1 Filter.

The old exchange was built by the Helsby Cable Co. of Liverpool in 1908, and the new by the derived company, The Automatic Telephone & Electric Co., so that both old and new exchanges were installed by virtually the same contractor. A feature of the Helsby exchanges is the location of the cord circuit relays and condensers on racks in the wide gangway at the rear of the switchboard. The amount of equipment mounted in the positions is, therefore, negligible, with consequent easy access to wiring and the cord shelves.

On the whole, the original switchboards, apparatus and wiring are still in good working condition and reveal satisfactory standards of construction and maintenance.

The following schedule gives a purview of the provision made for subscribers at Kingston :

	Subscribers	Subscribers' Calling Equipments	Multiple	Capacity
Old Exchange	5,700	6,650	6,700	8,000
New Exchange	5,700	6,440	7,200	10,000

The new exchange building in Birkenhead Avenue presents a most distinctive appearance, as shown in Fig. 1, which gives a good impression of the glossy black surface of the Derbyshire marble used as a wall covering. This new departure in exchange buildings is a pleasing attempt to follow modern tendencies which harmonise with the amenities of the surrounding property.

In addition to the exchange equipment, the building accommodates the service observation centre for 24 manual and automatic exchanges in the south-west area of London. Four observation panels are provided, two dealing with automatic exchanges and two with manual exchanges. Line-tapping equipments at these exchanges transmit subscribers' outgoing and incoming call conditions over junctions to Kingston exchange, where an allotter switch connects a free observation panel to the incoming junction equipment. This equipment operates lamp signals on the panel signifying

(*a*) the junction *number* in use (green lamp) ;
(*b*) that the subscriber is *originating* a call (white lamp) ;
(*c*) that *metering* conditions are being applied (red lamp) ;

FIG. 2.—AUTO-MANUAL EXCHANGE.

(*d*) on the same red lamp, that an *incoming* call to the subscriber is under observation.

On the auto exchange panels there are display lamps which indicate the number dialled. Display lamp-panels are also fitted on the manual exchange panels in readiness for eventual conversion of the exchanges to automatic working.[1]

(*b*) Enquiries from Kingston area subscribers re difficulties with calls and matters relating to service. There are 17 " A " or enquiry positions.

(*c*) Service P.B.X. traffic (one position with 26 extensions).

(*d*) Trunk offering, subscribers' emergency and subscribers' interception facilities (one position).

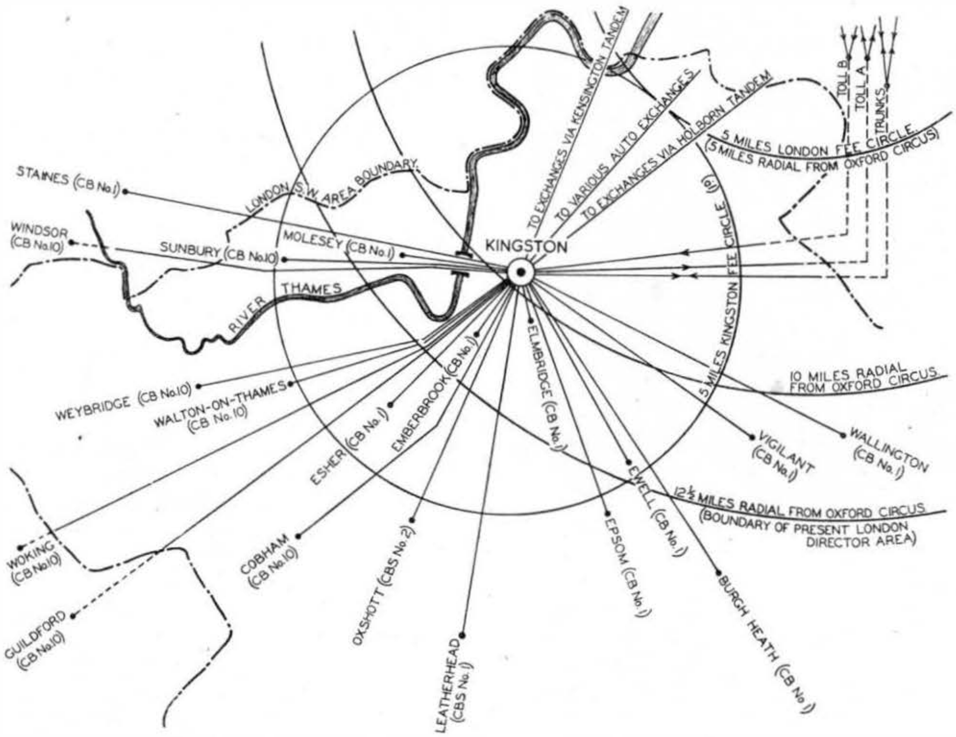


FIG. 3.—JUNCTION ROUTES TO AUTOMATIC, MANUAL, TRUNK, AND TOLL EXCHANGES.

The Auto-Manual Board.

The new Kingston exchange has been installed with 2,000 type director equipment with an auto-manual exchange of 28 sleeve-control positions of the standard type used for London exchanges. A view of a part of the switchroom on the second floor is shown in Fig. 2. These positions deal with :

(*a*) Control of the Kingston subscribers' traffic, incoming and outgoing, for the London toll area, which is approximately 40 miles, radially, beyond the director area.

Traffic between the London south-west area manual exchanges and Kingston which is transmitted direct to Kingston as depicted in Fig. 3. This figure illustrates the convergence on Kingston of telephone traffic in this part of London's suburbs and, further, shows the whole of the telephone routes to Kingston.

The calls to Kingston subscribers from other exchanges in the toll area are routed via Toll " B " to the toll suite of 9 positions at Kingston where the calls are completed over the outgoing junction multiple. Calls in the reverse direction are routed via Kingston manual board to straightforward junction positions at Toll " A " exchange and to exchanges in the toll area.

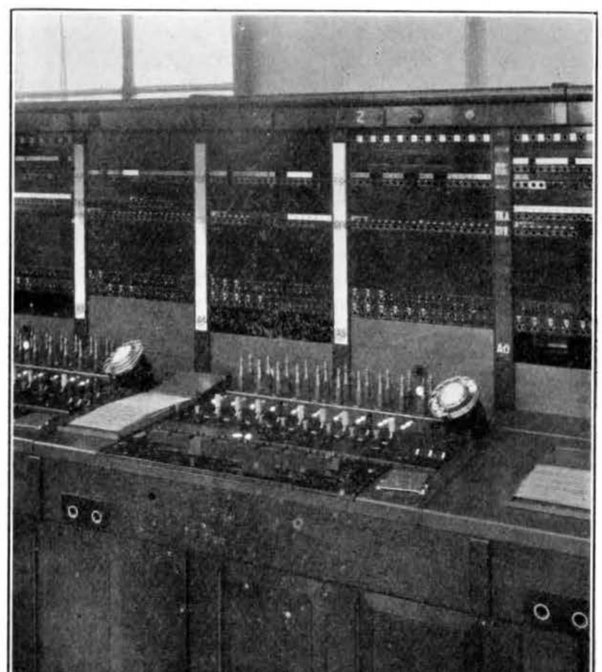


FIG. 4.—TOLL POSITION.

[1] *P.O.E.E.J.*, Vol. 26, p.21.

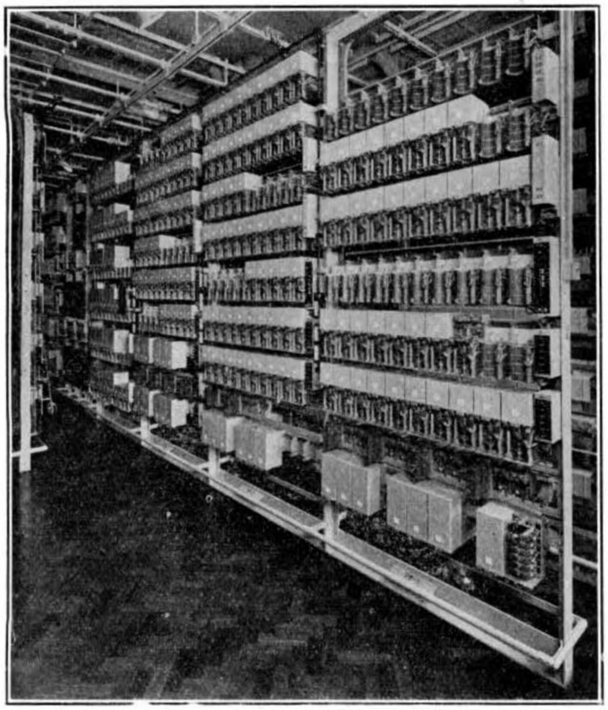


FIG. 5.—PRIMARY FINDER RACKS.

(*e*) Excess fee calls within the director area for coin-box lines.

The code level circuits from coin-box lines to exchanges beyond the local fee area (10 miles' circle) are connected to the manual board in order that the operator may verify the collection of the additional fee.

A close-up view of one of the 9 positions dealing with traffic to Toll " A " exchange, for the toll area, is shown in Fig. 4. The positions are 4 ft. 8½ in. high and 2 ft. 3 in. wide. This width is determined by the requirement for switchboard plugs of the " B " gauge, involving " B " gauge jacks at 1½-in. centres per strip of 20. Seven panels complete a 6-ft. 9-in. section of 3 positions.

The initial provision for answering equipments is 240 circuits arranged in a multiple with a complete appearance over 6 panels.

The equipped capacity of the outgoing junction multiple with 4 panels per multiple is as follows :

120 circuits with free line signals incorporating designation strips ;

100 circuits without free line signals, i.e. with designation strips only.

The complete multiple is common to both " Toll " and " A " positions. The circuits allotted to the free line signal section are :

A group to 1st numerical selectors for dialling Kingston numbers.

A group to M.B. 1st code selectors for dialling into the London network.

A loop calling group to Toll " A."

A C.B. signalling group to the trunk exchange for trunk demand calls passed from coin-box subscribers.

The non-free line signal section of the multiple comprises :

C.B. signalling junctions to exchanges outside the local fee area.

Transfer lines to other positions.

" ENG " lines to the test desk.

Miscellaneous service circuits.

A strip of cord test and tone demonstration jacks is provided on each position.

Each " Toll " position is equipped with 10 standard sleeve-control cord circuits with a Clock No. 44 individual to each cord for timing calls. A bulletin panel and card-index file complete the keyboard equipment.

Timing of calls is not controlled on the " A " positions, and Clocks No. 44 are omitted together with card-index files. Additional information cards required by the " A " operator are contained in a card-trough in the keyboard, one trough serving two operators.

The supervisor's desk is of the standard type with the usual facilities to the automatic network, manual board, test desk and listening-in lines.

Automatic Equipment.

The linefinder system has been provided and both the non-numerical and the main numerical switching apparatus employ the new 2,000 type equipment now standard for automatic exchanges. The basic characteristic of this equipment is an improved type of two-motion switch, the result of many years' research by the A.T. & E. Co., Ltd., and the Post Office Engineering Department. It is applicable to director, non-director and unit automatic exchange equipments, and has a greater bank capacity. Pre-2,000 type switches are limited to 3 banks. A view of 2,000 type 4-bank switches may be seen in Fig. 5. Each bank has ten levels of 10-pair bank contacts and each wiper spring has an individual

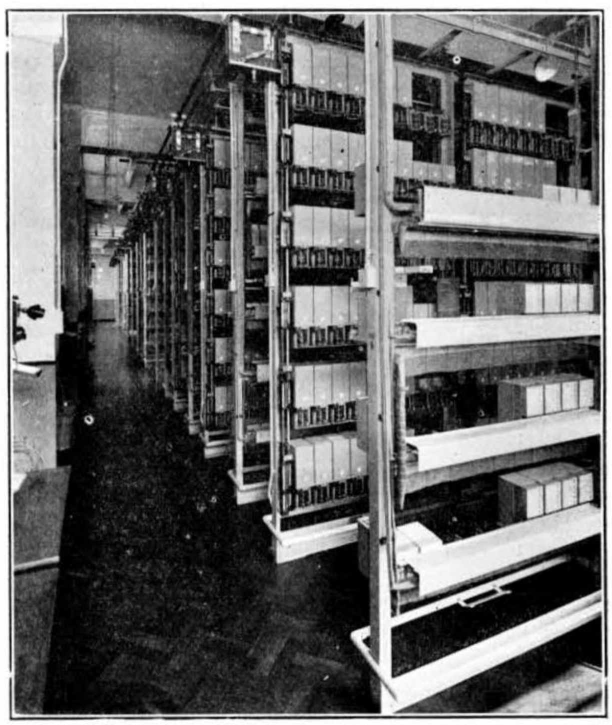


FIG. 6.—AUTOMATIC APPARATUS ROOM.

connector wire, the springs of a pair being separated by insulating material.[2].

Mechanical improvements include [3]:

(*a*) The spindle—fixed rigidly at both ends, obviating wiper bounce.
(*b*) A new design of wiper.
(*c*) Improved mounting of mechanically-operated contact springs.
(*d*) The light weight selector frame of aluminium and steel (90 per cent. aluminium).

Reduction in Rack Quantities.

The reduction in switch and, therefore, rack quantities effected by a reduction of the overall dimensions of the switch achieves desirable economy of floor space, and consequently in building accommodation, and it is estimated that a floor space saving of at least 10 per cent. should be obtained. The saving of space by the automatic switching plant at Kingston is greater than 10 per cent., as indicated by the following table comparing rack quantities, 2,000 type and pre-2,000 type, pertaining to Kingston.

Selector	Pre-2,000 Type		2,000 Type	
	Rack Capacity	No. of Racks	Rack Capacity	No. of Racks
Primary Finders ..	50	17	60 & 70 (See note)	13
Secondary Finders ..	108	2	112	2
"A" Digit Selectors ..	60	2	70	1
Directors	10	12	20	6
1st Code Selectors (Ordinary and Barred Trunk Subs.) ..	30	18	40	13
1st Code Selectors (Manual Board) ..	30	1	40	1
Group Selectors (2nd and 3rd Code 1st and 2nd Numerical)	60	35	80	26
Final Selectors (Ordinary, 2-10 P.B.X. and 11-20 P.B.X.) ..	50	20	60	16
Final Selectors (over 20 P.B.X.) ..	50	2	50	2

NOTE: Racks of primary finders wired in groups of up to 25 primary finders per group require 3 racks to accommodate 8 groups with the following auxiliary equipments:

8 start relay sets.
16 control relay sets with capacity for 24.
16 allotters with capacity for 24.

This auxiliary apparatus requires 2 shelves each on 2 racks and 3 shelves on the third rack, which can accommodate, therefore, only 60 primary finders. The two former racks accommodate 70 primary finders. In Fig. 5, the P.F. rack No. 3 is equipped with 3 shelves of auxiliary apparatus and has capacity, therefore, for only 60 primary finders.

In this figure the cover of the 8th finder on shelf D has been removed, exposing the mechanism and revealing the great reduction in dimensions (about 40 per cent.) of the 2,000 type mechanism. This is made possible by omission of the release magnet and the re-design of the other components. Release action is obtained by automatic rotation of the wipers past the last (11th) bank contact where it is free to drop to the normal level and return to the normal position under tension of a helical restoring spring which is fixed on the spindle.

Rack Equipments.

All the automatic switching racks are on the first floor, a general view of which is given in Fig. 6. Although this floor is well equipped with racks, good natural lighting is available throughout. The clear runway afforded for the negative and positive busbars is noticeable in this view, also the 125 amp. feeder fuse panels with their suspended alarm lamps.

If, in any circumstances, there should be a discontinuity of the 50 volt supply, it is arranged that 50 per cent. of the rack feeder fuses be disconnected by the maintenance staff. For this purpose, alternate

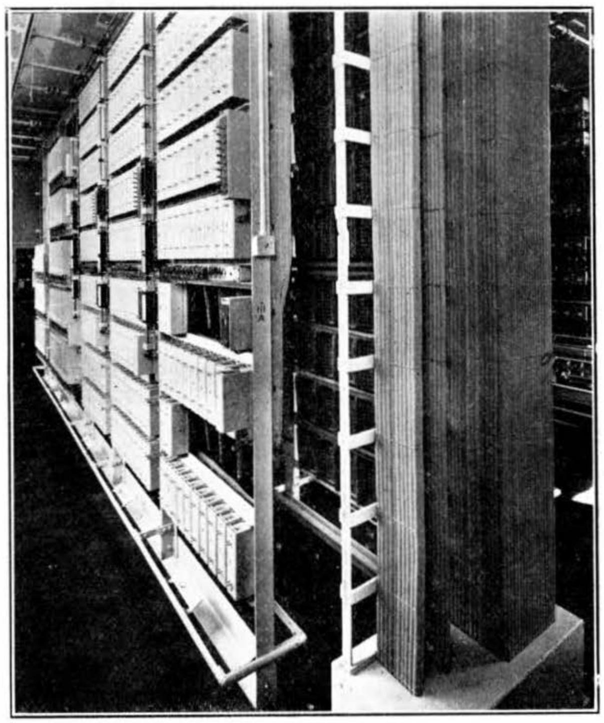


FIG. 7.—SUBSCRIBERS' L AND K RELAY RACKS.

feeder panels have a vertical white line parallel to the busbars, and fuse-post spanners are ready for use on the wall. This ensures that on restoration of the supply, the sudden load, due to closed selector circuits, should not exceed the capacity of the main fuse or circuit-breaker. Subsequently all fuses are reconnected. Final selector racks are in the foreground and *en suite* with these are the subscribers' L and K relay racks, a separate view of which may be seen in Fig. 7. In this figure the neat formation of the rack cables passing through the floor to the I.D.F. on the ground floor is seen to advantage. The racks are provided with speaker circuits to the I.D.F. The sub-section alarm marking 111A can be seen on the

[2] *P.O.E.E.J.*, Vol. 28, p. 252.
[3] *P.O.E.E.J.*, Vol. 28, p. 249.

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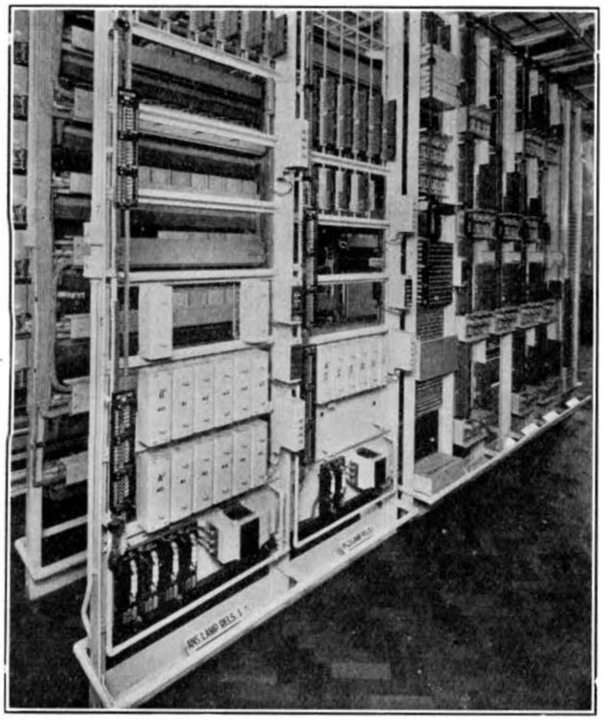


Fig. 8.—Lamp Relay Racks.

side of the end rack. The first digit indicates the floor number, the second refers to the section alarm number (in Kingston exchange the section covers the whole floor), and the third to the sub-section (a rank of switches) alarm number. The letter " A " beneath signifies the particular suite of racks.

The racks for the manual board answering and free line signalling lamp relays are so situated that the voltage drop in conductors to the positions on the floor above is kept at a minimum. Fig. 8 shows the lamp relay equipment in panel order, together with the traffic recorder control and access switch racks and the 3rd code selector T.D.F.

The subscribers' 100-type meters are located in a separate room on the first floor for convenience of meter reading.

The ground floor accommodates the M.D.F., I.D.F., test desk, relay set, miscellaneous apparatus, and service observation racks and the power plant.

Power Plant.

The power plant is operated on the divided battery float system. Two motor generators, one small and one large, are provided, which supply power to the exchange across a floating battery. Fig. **9** shows the power circuit arrangements as applicable for Kingston. The characteristics of the machines are as follows:

Motor Generator No. 1.

Input : 415 V A.C., 3 phase, 50 c/s.
Output : 51 V, 100 A.

Motor Generator No. 2.

Input : 415 V A.C., 3 phase, 50 c/s.
Output : 51 V, 300 A.

The machine equipment represents the initial provision and arrangements have been made for another 300 A machine to be provided when required. Each machine is provided with an automatic voltage regulator of the moving-coil type which maintains the supply voltage at the exchange discharge bars between the limits of 50·5 and 51·75 V. The two

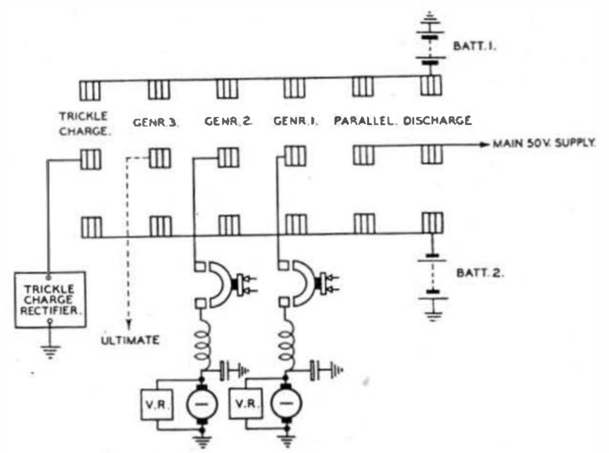


Fig. 9.—Power Circuit.

regulators can be seen at the bottom right-hand corner of the power switchboard in Fig. **10.**

A smoothing filter is provided for each machine to limit the audio frequency disturbance across the floating battery within the specified limits. Fig. **11** shows particulars of the filters, the design of which was based on measurements made on site.

The main battery is duplicated, each battery being initially plated to 1,200 Ah capacity with boxes for an ultimate capacity of 1,650 Ah. Under emergency conditions of mains failure, the two sets of 25 cells are paralleled by throwing a switch on the power board, and sufficient capacity is available for approximately 24 hours. The main discharge busbars to the exchange each consist of four 4-in. by $\frac{3}{8}$-in. copper

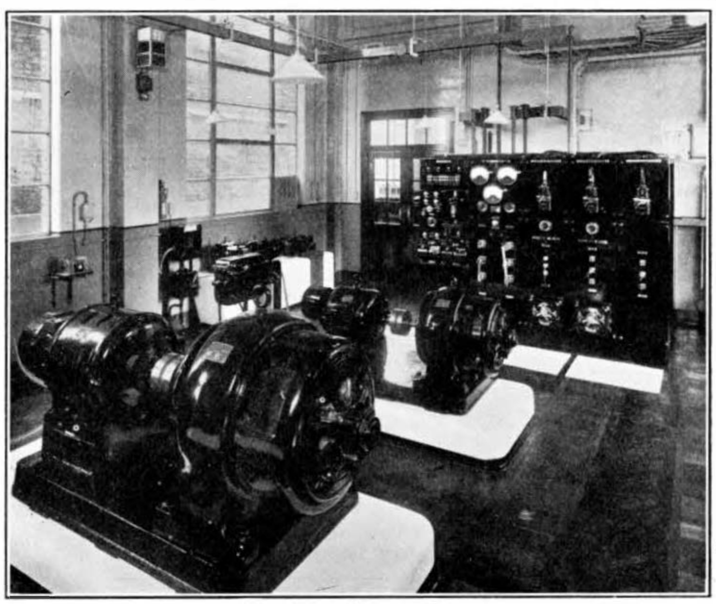
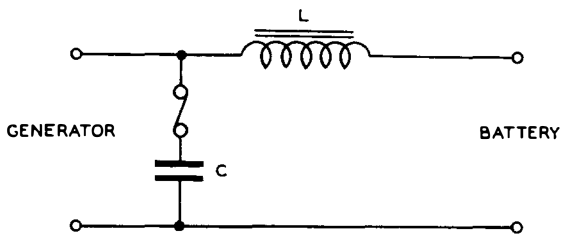


Fig. 10.—Power Plant.



GENERATOR No.	FUSE R.C. AMPS	L		C μF.
		RATED CURRENT AMPS	INDUCTANCE mH	
1	10	100	2·5	500
2	40	300	1·88	4000

FIG. **11**.—SMOOTHING FILTER CIRCUIT.

bars designed to carry an ultimate peak load of 560 A on the basis of 1 V P.D. between the battery lugs and the farthest feeder point in the exchange.

Standard ringing and tones are provided by power-and battery-driven ringers, each having an output of 75 V 1 A at 16⅔ c/s. The ringing panel is equipped with duplicate tone filters, one set for each machine, and a two-step auto-starter for the standby ringer.

Exchange Trunking.

The trunking arrangements are shown in Fig. **12**. In addition to normal dialling facilities, Kingston subscribers have been instructed to use the dialling codes on calls to the four manual exchanges shown in the diagram (Note 4). Such calls are completed by the manual exchange operators. The codes do not correspond with the digits represented by the first three letters of the exchange names which, for Elmbridge is " 356," not " 316." The exchanges are scheduled for conversion to automatic working, and if the exchange-name code " ELM," etc., were used now, the psychological probability is that the subscribers would continue to dial the code, omitting the exchange number, after the introduction of automatic working. As these exchanges are converted, Kingston subscribers will be re-instructed regarding the dialling codes.

Circuit Arrangements.

From the circuit point of view, the introduction of 2,000 type exchanges has involved extensive re-design. Besides revision necessitated by the improved functions of the two-motion switch, the new circuits[4] include developments prompted by research. These include :

(*a*) The " balanced tones " method of applying dial, busy and N.U. tones through an additional winding of the line relay.
(*b*) Battery testing instead of earth testing.
(*c*) The decisive functioning of the B or guard relay.
(*d*) Greatly improved operation of the linefinder.

Acknowledgments.

The Contractors who have carried out the various works in accordance with the Post Office specifications are as follows :

Automatic switching plant, auto-manual switchboards and power and ringer panels :—Messrs. Automatic Telephone and Electric Co., Ltd., who kindly provided photographs for this article.

Motor generators and ringing machines :—Messrs. Electric Construction Co., Ltd.

Batteries :—Messrs. Alton Battery Co., Ltd.

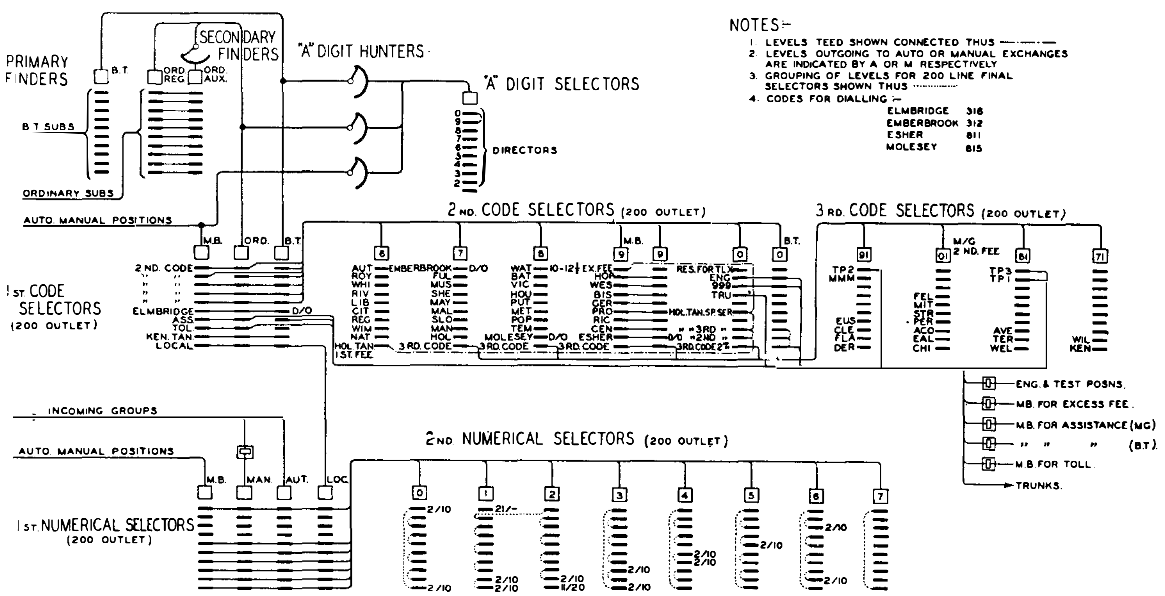


FIG. **12**.—TRUNKING DIAGRAM.

The assistance given in the preparation of this article by colleagues in the London Telecommunications Region Headquarters and in the local area is gratefully acknowledged.

[4] *P.O.E.E.J.*, Vol. 29, p. 87.

Artificial Life Tests of Cords and Flexible Conductors

U.D.C. 620.15: 621.315.45

O. S. STILES and
F. J. W. LIDSTONE

The authors describe machines developed by the Post Office for making, on flexible conductors, artificial life tests under conditions of bending, kinking, abrasion and twisting.

Introduction.

MODERN telephone development has shown the necessity for artificial life tests on instrument and switchboard cords, and in order to facilitate the development of non-extensible and extensible cords and cordages suitable for use by the Post Office it was desired that machines be designed and built for testing the durability of various cordage constructions existing and projected.

Until recently no suitable machines were available for this purpose, but such have now been designed and constructed at the Post Office Research Station, Dollis Hill. These cater for tests on the two main classes of cords, viz., instrument and switchboard, and a programme of tests was agreed upon tentativelywhich in broad principles reasonably simulates the use of cords likely to be met with under practical conditions. By this means it was considered that undue complication of the machines could be avoided; machines could be produced at reasonable cost, and no difficulty would be met with in the matter of repetition tests.

Field trials of instrument cords, although producing some useful data, have not, so far, provided conclusive evidence, and the life testing of switchboard cords by actual manipulation employing girls at an exchange switchboard, has proved a tedious and unreliable process. In addition to tests of complete cordage constructions it will be appreciated that the bare tinsel conductors on which the cordage is built should also be investigated with a view to possible improvements on those in use at present.

Tinsel Tests

Machines for bending tests on tinsel and similar flexible conductors have been in use for some considerable time both by manufacturers and the Post Office, and were constructed to conform to the requirements given in the Post Office specifications. These call for a bending test of the tinsel conductors, and in the earlier machines the mechanism consisted simply of fixed and movable clamps in guides, to which a few samples of tinsel conductor or rope could be attached, the movable element being given a reciprocating motion, causing the tinsel to bend alternately into a " bight " and to straighten out.

The latest type of machine to satisfy the specification requirements is now in use in the Durability Laboratory and is shown in Fig. **1**.

Briefly, the machine consists of a central reciprocating platform A, to which one end of each of 12 test samples can be fixed. Parallel with and ranged on either side of the central platform are two other similar platforms B and C, rigidly bolted to the cast-iron bedplate E measuring 11½ in. by 11 in. To B and C are fixed the other ends of the test samples D.

A reciprocating motion is imparted to the central platform by a connecting rod F and crank with a throw of ½ in. The crankshaft is driven by a gear-cum-belt drive from a 1/30th h.p. A.C. motor. The speed of the test platform is 500 reciprocations per minute, a gear-driven meter I being provided to count the reciprocations.

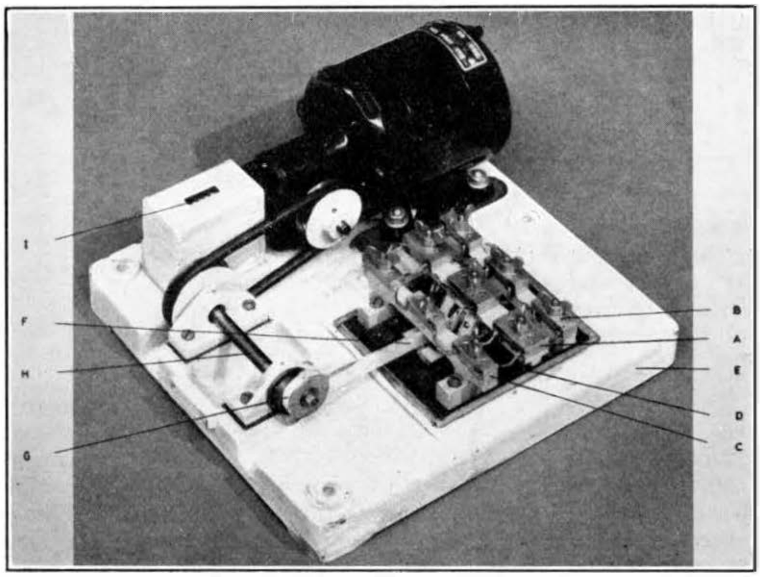


Fig. **1**.—Tinsel Testing Machine.

This machine has been in considerable use and, so far as can be ascertained by results, has been very satisfactory.

Mounting of Test Specimens.

In the tinsel test machine illustrated one continuous length of tinsel rope can be used for all specimens if required. In the application of the rope to the machine, use is made of a special bridge (see Fig. **2**) which is designed to ensure that the correct length of specimen is used.

The bridge is made in metal and is constructed in two parts to facilitate its removal from the machine after the rope specimens have been " set." It is wedge-shaped in section, the height from base to apex being 3/32 in. greater than the normal axis of the " rope " specimens when pulled straight, above the upper surface of the machine base-plate. With the bridge in position and a tinsel rope specimen stretched across, it will be seen that a little extra length of specimen is thus obtained; this is considered sufficient to ensure that the test specimen will not be subjected to undue end strain during the test.

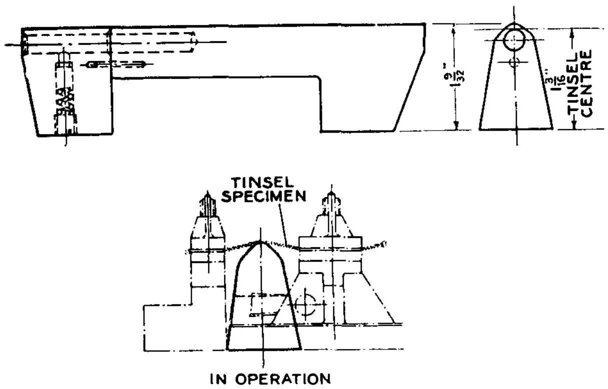


FIG. 2.—BRIDGE FOR ADJUSTING LENGTH OF SPECIMEN.

The use of the bridge ensures strict comparability of results with tinsel ropes of equal diameter.

The rope is woven backwards and forwards through the clamps on platforms A, B and C, being " teased " into position against the guide pins through the blocks of the clamps and with enough slack left at the ends for final adjustment.

The rope is finally set with the clamps at $\frac{7}{8}$ in. apart. Working from A-B or A-C, with the bridge in position, the rope is pulled up tight against the tightened clamp A, adjacent lengths of the rope being manipulated together. The appropriate clamps are then tightened and the same procedure followed on the other and adjacent pairs at the same end of the machine, the slack being worked out at the end B or C as the case may be. The bridge is then withdrawn and the whole procedure followed out again at the other end of the machine.

Examination.

Examination of test specimens is normally made after 50,000 reciprocations for tinsel ropes of instrument cordage, or 200,000 for ropes for switchboard cords.

The test specimen is cut cleanly away from the clamps, using a razor blade, the cut being made 1/16 in. away from the blocks. This ensures that the specimen does not contain any part damaged by stresses set up at the outlets of the blocks and only rope actually bent in the centre is examined.

The specimens of rope when detached are carefully de-stranded, each strand being tested electrically for continuity ; the percentage failures are then calculated and recorded. Specimens of one make of rope are generally tested together when possible, but ropes of different makes may be tested together if required.

MACHINES FOR GENERAL TESTS OF NON-EXTENSIBLE CORDS

Owing to the impracticability of trying to simulate in one machine all the varieties of stress and wear likely to be encountered in practice, it was considered preferable to adopt a series of simple tests which could always be repeated, and which would not call for undue complication in the design of the testing machines. For these reasons six tests were decided upon as illustrated in Fig. **3**, these being intended for cordage of the non-extensible type only.

The tests referred to are arranged to simulate, in general, the dragging, kinking, twisting and abrasive movements of instrument cords and the steady tensile, bending and abrasive movements that switchboard cords are subjected to.

Five of these tests can conveniently be provided on one machine ; it was realised that test 5, which is a twist test, would require a separate machine with the object of preventing undue complication.

A preliminary design of machine for tests 1, 2, 3, 4 and 6 was manufactured at the Post Office Factory, Holloway. The machine is driven by a $\frac{1}{3}$ h.p., 3,000 r.p.m. motor, through a 5 : 1 reduction worm gear. The slow speed shaft carries a crank disc and connecting rod to impart reciprocating motion to two sets of cord-testing platforms operated in tandem. The latter are supported on two rod side members which also act as slides. To these movable platforms is affixed one end of each of the cordage samples to be tested, the other ends being attached to similar platforms firmly clamped to the side members. This machine was used considerably in early tests of cords, and from the experience gained a new improved type of machine was developed on which to make the tests already described. Two models of the latter were constructed. Fig. **4** shows complete assemblies, including the tinsel machine.

The new machines are arranged for balanced reciprocation, each machine being divided into two units for this purpose. They are each driven by a 0·25 h.p., 1,400 r.p.m. motor, with double reduction gears giving a final shaft speed of 135 r.p.m. The transmission is by sprocket and chain, giving machine speeds of 100 and 200 r.p.m. No ' change speed ' gear is provided, the gear chains being changed by hand to the sprockets required. The motors are situated below the machines, and it will be seen that the upper driven sprocket S1 drives a short shaft having balanced crank arms CA at each end. Connecting rods transmit a reciprocating motion to the slide blocks SB, these moving a fixed distance of six

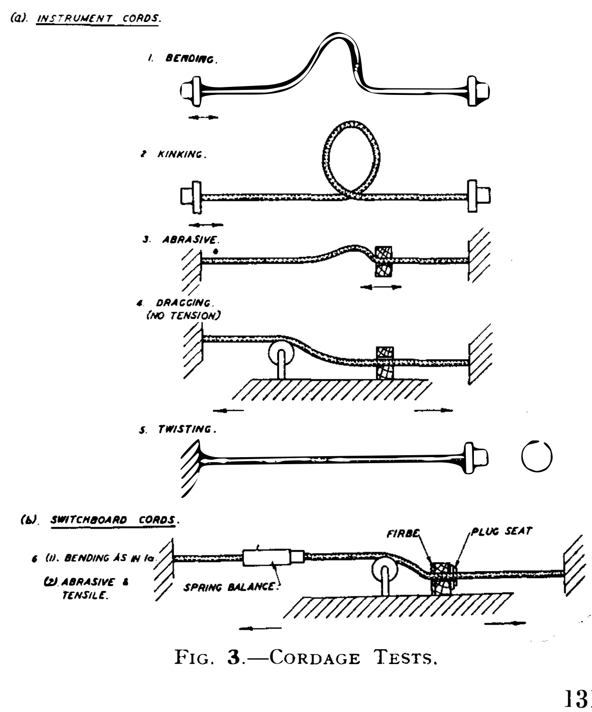


FIG. 3.—CORDAGE TESTS.

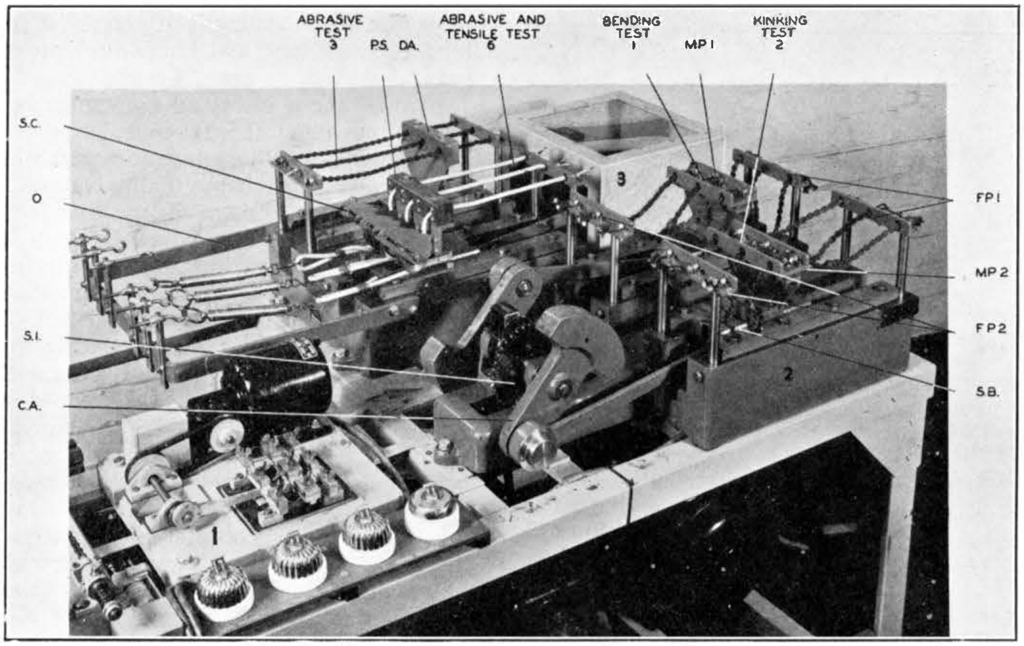


FIG. 4.—MACHINES FOR CORD AND TINSEL TESTING.

inches in suitable guides on the bed-plate of each machine. On the slide blocks are fitted moving platforms MP, to which six samples of cordage per unit for bending and kinking tests 1 and 2 can be attached. This being the moving end, the other ends of the test samples are fixed to elevated platforms FP rigidly fixed to the base.

For tests 3, 4 and 6, other fittings are employed, e.g. in test 3 the cord clamps used on MP in tests 1 and 2 are replaced by a wooden bar DA with large holes through which the test samples pass. This is the means whereby abrasion of a cord over, say, a desk edge, is simulated, the cord sample in this case being clamped at each end, but lying quite loosely in between the clamps. The set-up for test 4 is similar to that shown for test 6 except that the central moving block through which the cords pass is the same as employed in test 3 and no tension is applied, the cord again lying limply in between the end clamps and dragging under the pulley sheave. An outrigger O is fitted to the machine as in test 6 to take the extra lengths of test specimen and the spring balance if and when required.

In test 6 the central abrasive block PS simulates a section of the plug shelf of an exchange switchboard, it being faced on one side with red fibre and on the other at each hole with a Seat, Plug, No. 3. The angle at which a cord emerges from a plug shelf is catered for by the pulley sheaves shown, which can be set to give any angle between 10° and 90° by fixing them at the right positions along the slotted carrier SC, the pulley sheaves also simulating the rolling action of the cord weight on the cord. Tension is provided by spring balances reading up to 2 lb. in half-ounces.

Both machines are fitted with Veeder-Root re-set 5-digit, type A.G., revolution counters, which are driven by 2 : 1 reduction gear from the crankshaft. Protective covers are provided over the cranks, sprockets and chains of the drives, one of these being shown on Machine No. 3 (Fig. 4).

On these machines provision has been made for various convenient lengths of test specimen, and these can at present be of any diameter up to 5/16 in. solid. The outlets and saddle clamps fitted on the moving and fixed test platforms are of larger diameter than the cords, the difference in diameter being made up by a serving of rubber tape in each case. At least three inches extra length is always allowed at each end of the test specimens for terminations and electrical test connections. For tests of cordage the ends of the test specimens, after being served with rubber tape and clamped under the saddle clamps of MP1 and FP1 or FP2 for anchorage, are connected to the plate terminals fitted to the platforms (not shown in photographs). This is for ease of making microphonic noise tests without disturbing the test specimen.

For tests 1 and 2, bending and kinking, the test samples can be extended from FP1 to FP2 in one continuous length, or in two halves as desired.

To avoid undue stresses when the specimens of stiff cordage are at maximum extension, an extra length for slackness is allowed. This will vary with the type of cord tested, as it is found that circular cords are generally much stiffer than cords of the plaited type.

For test 1 the setting requires that the specimen should be "just not tight" when fully extended without twist or kink.

For test 2 the necessary kink is set in the cord specimen initially by giving it a one-turn twist, right or left-handed as desired, with the cord at its greatest extension and before being finally secured under the saddle clamps.

For test 3 (abrasive) the specimens are secured at FP1 and FP2, the slack allowed being as in tests 1

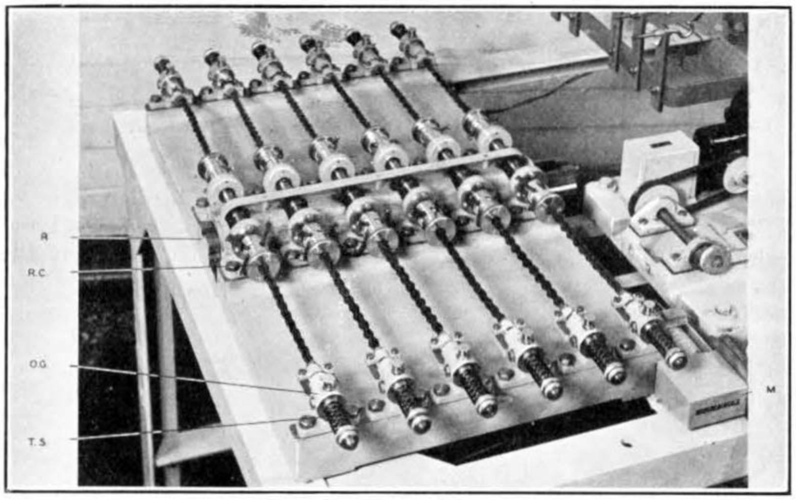


FIG. 5.—TWIST TESTING.

and 2. In this test the mounting MP2 is removed and replaced by abrasive block DA.

Test 4 (dragging, no tension) makes use of most of the fittings required for tests of switchboard cords, i.e. No. 6, but in this test block DA replaces PS. The cord is rove through the pulley sheaves and DA, and terminated, one end on FP1 and the other end in the same way as switchboard cords, i.e. the end bent back on itself and anchored to the end hooks on the outrigger O by a lashing of twine. The spring-balance is not then required.

The amount of drag can be regulated, within limits, by positioning the pulley sheaves in the slotted carrier SC. It should be noted, however, that changes in drag will be accompanied by changes in the abrasion from block DA. No set amount of drag can be standardised, but, provided that the pulley sheaves are set similarly to one another in SC, reasonably comparative results should be obtainable.

Twisting Tests of Cords—Test No. 5.

For the special requirements of this test a separate machine was provided and, as with the other machines, preliminary experience was gained on experimental models.

On the latest machine (see Fig. 5) arrangement is made for driving twelve rotating chucks RC to which cord samples can be affixed. The rack R is reciprocated by a motor and gear-driven crank arm situated below the cast-iron base on which the whole is mounted. The chucks each have a coned grip internally which secures the conductors of the test specimens, the ends projecting as seen in the illustration through outlets in the body of the chuck. These chucks will grip any size braided or unbraided conductor within wide limits, and if the ends are evenly distributed a uniform and satisfactory anchorage is ensured. On the same axis and situated some six inches away are the anchorages OG for the other ends of the test specimens. These ends cannot rotate, but are free to slide axially against the tension of helical springs TS. This spring anchorage is intended to relieve the fixed end of any appreciable stresses when the cord is fully twisted, as, if not provided, the test specimen is liable to break at this point.

The machine gives each chuck one complete turn from zero twist and back again, doing this 120 times per minute. A 7-digit meter M, operated through contact springs by the crank arm underneath the machine, counts the number of complete twists given.

Noise Test.

Listening tests are made at intervals on the cords while still under test on the machine, the conductors being in their appropriate positions in the circuit of a telephone instrument No. 162. Feeding current is supplied by a "Stone" transmission bridge, simulating the exchange end of a subscriber's line.

The connections are shown in Fig. 6, the conductors of the test specimens being connected to the test lead terminals. Provision is made for testing three or four conductor cords, the switching keys being arranged to cut the conductors into circuit as required. This is of considerable use in localising the noise, as it may not necessarily occur on all conductors at the same time. An instrument for the objective measurement of continuous spectrum and intermittent noises of this character is not available, but in order to obtain a figure for comparison purposes use is made of the psophometer, although the latter is intended for continuous tones of a limited number of frequencies. This measures the equivalent 800 c/s voltage across the receiver of the listening instrument.

Tentatively a figure between two and three millivolts is taken as indicating noise of a disturbing level. When the noise reaches this value the cord is broken down for examination.

Experience has shown that the twist test takes considerably longer to reach a state where noise is observed than do the other tests 1, 2, 3, 4 and 6. It

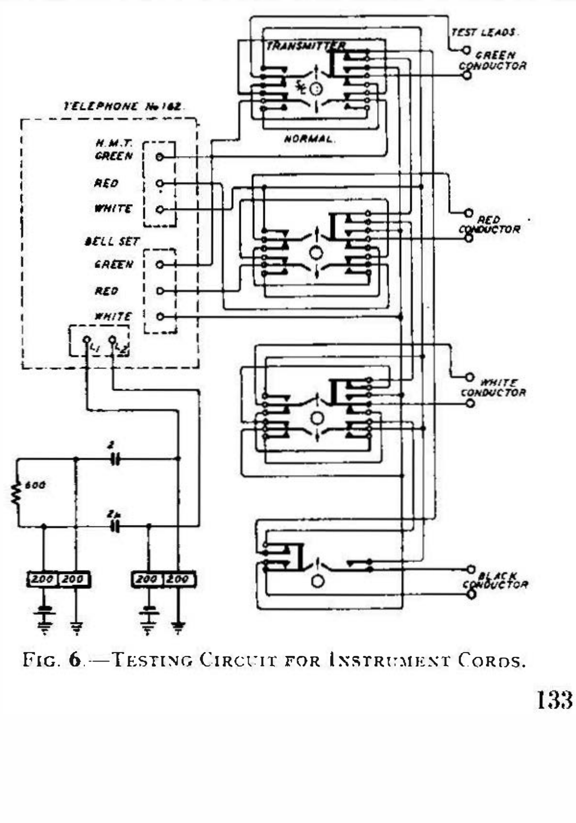


FIG. 6.—TESTING CIRCUIT FOR INSTRUMENT CORDS.

is therefore only necessary to make listening tests at rather infrequent intervals. The test periods may vary according to the character of the cord being tested and no hard and fast rules can be laid down. It is, however, necessary to make the observations more frequently after the first indications of noise have been observed.

Examination of Cords.

When specimens are taken off test for examination, only that part of each which has been subjected to the particular test conditions intended is examined. For example, in tests 1 and 2, of the part actually "bent" or "kinked" only the middle portion, say four inches, is taken, and not end sections at the anchorages. Note is made of any breakages of textile coverings, and the conductors are dealt with in the manner explained under tinsel tests examination.

Machines for Tests of Extensible Cords

The development of an instrument cord of the extensible type has necessitated the introduction of a suitable testing machine. An experimental machine was developed, but this was subsequently replaced by the machine shown in Fig. **7**, which subjects the cords to life-tests under stretching conditions.

The motor M drives through a reduction gear, two crank arms A, one on either side of the machine ; to each of these are attached two pulling cords terminated on a stirrup which engages a pin B. These cords pass round " common " pulleys P and P1, then divide and pass over pulleys P2 and P3 to their respective termination on bar SB of the cord-stretching frame. It will easily be seen that this mechanism provides a raising and lowering motion to the frame, the extent of which motion is adjustable.

The stretching-frame consists of upper and lower bakelite bars SB and SB1 fitted with connection plates for conductor termination and drilled with holes at equidistant centres for anchorage of the cords. The bar SB is adaptable for testing various lengths of manufactured cords ; the sub-frame USF allows different lengths to be tested simultaneously. Usually the stretch given in the tests is 50 and 100 per cent. over the normal length, but this can be varied to suit requirements. The cords are stretched vertically throughout their entire length and on release to the slack condition the normal length is reached and passed, the cords coiling up naturally, giving a right-angled bend at the lower bar termination, which, it is considered, simulates quite reasonably the conditions met with in practice on a subscriber's instrument.

The stretching-frame has accommodation for 12 cords per side, and the maximum distance to which the cords can be stretched is 66 in., giving 100 per cent. stretch to the longest cord so far tested.

Anchorage holes, suitably chamfered for the cord ends, are situated in both top and bottom bars of the stretching-frame, these being drilled at 1¼ in. and 2¼ in. centres. The top bar being flexibly mounted is guided in its motion by ½ in. diameter side rods.

The main drive is from a geared unit driven by a 240 V, A.C. motor, and giving a working speed to the machine of 15 stretches per minute.

Examination.

This will generally depend on the amount of microphonic noise heard, and until this gets bad and likely to interfere seriously with conversation the cords are kept under test. To save time in examination only the conductors giving noise are broken down ; they are then examined for continuity as with other types of cordage (non-extensible), specimens being cut from the ends and centre of the cord lengths for examination.

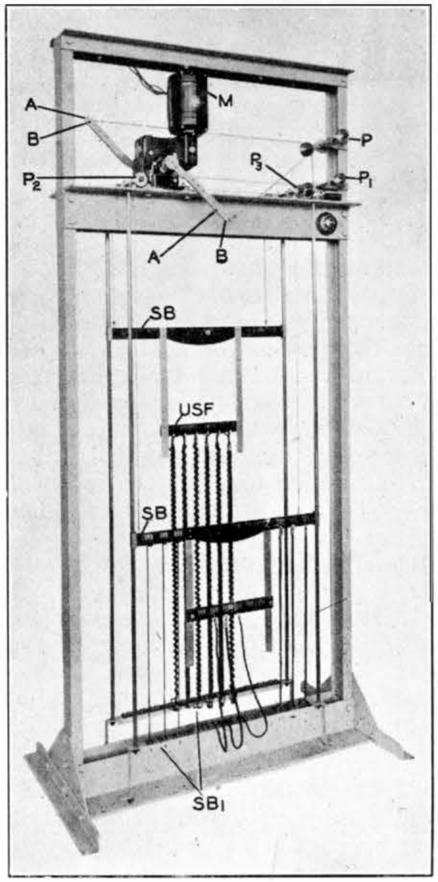


FIG. 7.—CORD STRETCHING MACHINE.

Conclusion.

The machines described in this article were designed and developed at the Post Office Engineering Research Station, Dollis Hill. Machines are in use for similar purposes by various telephone apparatus contractors, but those described represent some of the latest developments in machines for the life testing of telephone instruments and switchboard cords.

The Operation of Filters in Parallel

H. STANESBY, A.M.I.E.E.

U.D.C. 621.391.312

The article discusses methods of operating a number of band-pass filters in parallel, with particular reference to the procedure followed in designing the terminal equipment for the London-Birmingham coaxial cable. Special attention is given to the connection of filters having pass-bands which are contiguous or overlap.

Introduction.

WHEN it is necessary to connect several band-pass filters in parallel the technique that should be employed if satisfactory results are to be obtained, is not as clearly defined as that of designing an isolated filter. For this reason the methods that are adopted are not perhaps so well known.

The terminal equipment used on the London-Birmingham coaxial cable provides several interesting examples of the operation of filters in parallel. For instance, in both the sending and receiving sides at each terminal eight different channel filters are paralleled at the point where they connect to the group equipment ; similarly the five group filters in a super-group are connected to a common circuit. It is proposed to explain briefly the procedure that was followed when this equipment was designed.

Input Impedance of Individual Filters.

Before the problems associated with the parallel connection of filters can be appreciated it is necessary to consider how the input impedance of an individual filter varies with frequency. If a number of band-pass filters is to be connected in parallel, the ends of the filters at which paralleling is to take place should each terminate in a series arm of the prototype ladder structure[1], or its equivalent, in order that the impedance of each filter may rise outside its own pass-band. Under working conditions the general character of the curve connecting input impedance and frequency for each individual filter will be similar to that shown in Fig. **1** (a), and the transmission-frequency characteristic will be of the form shown against (b) in the same figure. It will be seen that the impedance is fairly constant and mainly resistive within the pass-band, but outside it rises rapidly and becomes almost entirely reactive. The curves used to illustrate this point were obtained from one of the group filters used in the broad-band modulating equipment.

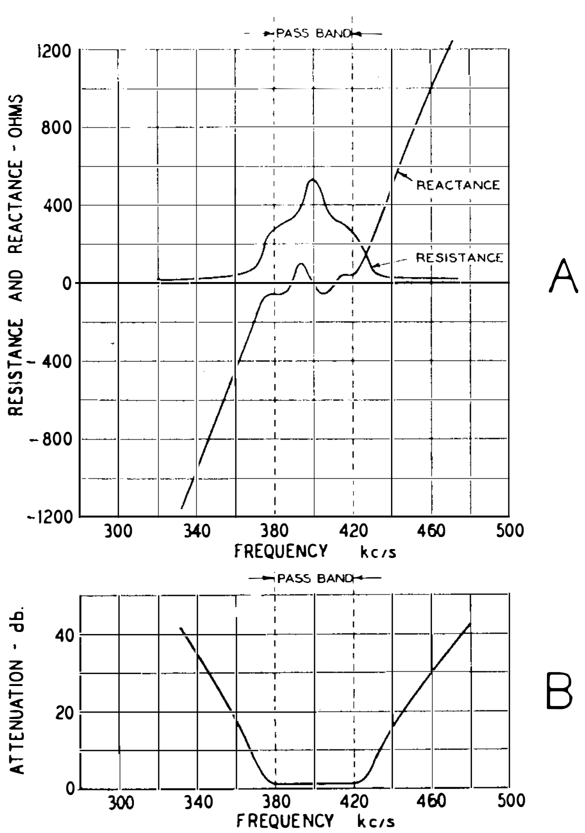


FIG. 1.—INPUT IMPEDANCE AND TRANSMISSION CHARACTERISTICS OF GROUP FILTER.

Gaps Between Adjacent Pass-Bands.

If the pass-bands of the filters which have to be paralleled are separated by gaps which are considerably wider than the pass-bands themselves, there is no difficulty at all and the filters may be connected directly in parallel. In its pass-band each filter will be shunted by a high reactance, due to the presence of the other filters, and this reactance will be so high, owing to the large gaps between adjacent pass-bands, that it will not affect the performance of the filter appreciably. These conditions obtain for the filters which are used to select various carrier frequencies from a train of harmonics in the carrier generating equipment.

A little more attention is needed when the pass-bands are not spaced so widely apart. It will be assumed that the pass-bands are all of the same width and are spaced evenly in frequency, conditions which usually obtain. As before, the filters may be connected directly in parallel, but there will now be a difference in that the reactance components shunted across each filter by its neighbours will be lower, owing to the narrower gaps between the pass-bands. The filters above and below will contribute components which are opposite in sign and therefore tend to correct one another, and this mutual correction of the shunt reactance components will be adequate for a filter having its pass-band symmetrically disposed with respect to those of other filters, but where most of the pass-bands are on one side or the other the resultant shunt reactance may not be sufficiently high. It is often necessary therefore to connect an auxiliary network across the complete system, as indicated in Fig. **2**, to compensate for the shunt

[1] The best values for the elements of the series arm may be different from those used for the normal mid-series termination ; see E. A. Guillemin, " Communication Networks," Vol. 2, p. 360, et seq.

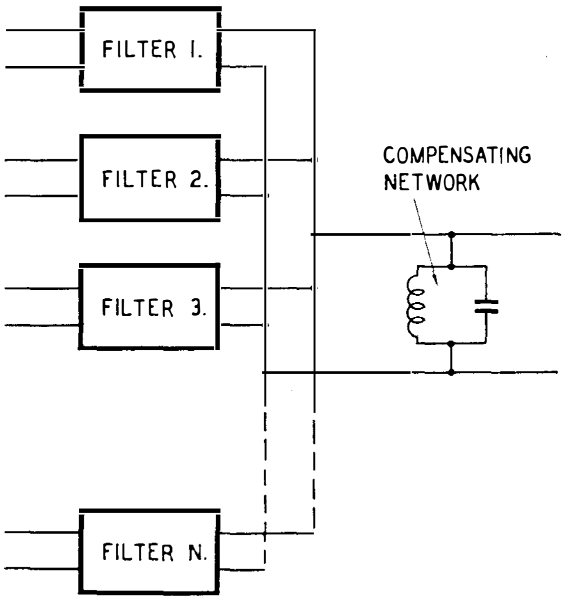


FIG. 2.—USE OF COMPENSATING NETWORK.

reactance. This method has been adopted for paralleling the channel filters.

No Gaps Between Pass-Bands.

When the pass-bands of the filters that have to be connected together are contiguous or overlap the problem must be solved in another way. Consider the example illustrated in Fig. **3** in which the substantially flat portions of adjacent pass-bands abut. At the common boundary of two pass-bands the input impedances of the two filters corresponding, will be largely resistive and will have the same value ; if the filters were connected directly in parallel they would therefore share any energy of this frequency supplied to them. On the other hand for frequencies well inside the pass-band of one of the filters, that particular filter would receive most of the energy. If therefore a number of filters having contiguous pass-bands were connected directly in parallel the transmission-

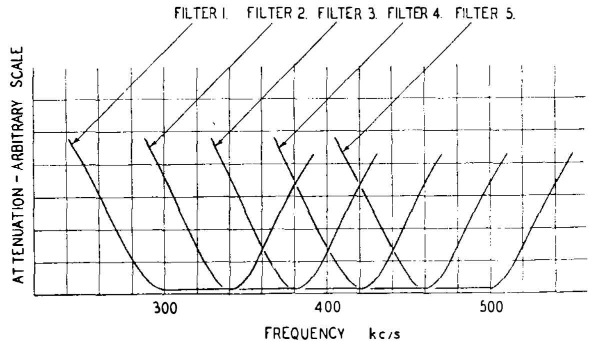


FIG. 3.—TRANSMISSION CHARACTERISTICS OF FILTERS HAVING CONTIGUOUS PASS-BANDS.

frequency characteristic of each filter would be adversely affected by the presence of the others.

It is necessary that the group filters in the broad-band modulating equipment have contiguous pass-bands ; similar requirements are also demanded of the super-group filters ; it has therefore been necessary to adopt some special arrangement for connecting the filters together. The problem may be stated in these terms :—The transmission loss between any one filter and the common circuit to which all the filters are connected should be independent of variations of the input impedance of filters passing adjacent bands. This may be accomplished in the following way. Numbering the filters consecutively according to the frequency order of their pass-bands, the odd and even numbered filters are separately paralleled and connected to opposite sides of a hybrid transformer ; the two remaining pairs of terminals on the transformer are connected respectively to a balancing resistance and to the common circuit with which all the filters are to be associated. The circuit arrangement is indicated in Fig. **4**. Referring to the figure the action of the hybrid may be described in two different ways :

(*a*) Consider an oscillator connected to the far end of one of the filters. If the impedance of the common circuit is balanced by that of the balancing resistance, the output from the filter which is energised will

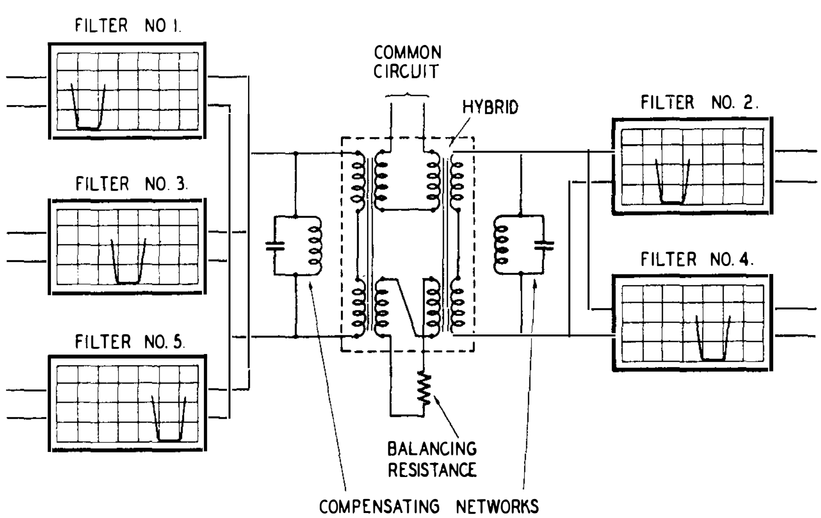


FIG. 4.—COMBINING CIRCUIT USING HYBRID.

divide equally between the common circuit and the balancing resistance, and none will flow into any of the filters connected to the opposite side of the hybrid. Assuming the transformer to be ideal the transmission loss of the filter and hybrid together will therefore be 3 db. higher than that of the filter alone at all frequencies. The transmission loss will, of course, be the same if the direction of transmission is reversed, from the principle of reciprocity.

(*b*) Assume an oscillator connected to the common circuit. If the oscillator frequency coincides with the common boundary of two adjacent pass-bands, then the impedances presented by the corresponding filters, one on either side of the hybrid, will be equal. The shunt reactances due to the other filters will be high and may be neglected, and the energy delivered from the oscillator will divide equally between the two filters. It will be observed that at this frequency no current will flow in the balancing resistance and that the loss between the far end of each filter and the common circuit will be 3 db. above the loss of each filter alone. For frequencies inside the pass-band of one filter the input impedance of that filter remains approximately constant, but the impedances of filters passing adjacent bands change. The hybrid is no longer balanced and some current flows in the balancing resistance. It can be shown that the magnitude of this current is such that the loss between the common circuit and the far end of each filter is 3 db. above the loss of each filter alone, assuming the hybrid itself to be free from loss.

The second explanation is perhaps the more informative. It reveals that this method of combining filters is in theory perfectly efficient in that the loss of 3 db. must under any circumstances be involved at the frequencies where two pass-bands abut. It provides in effect a means of rendering this loss of 3 db. constant throughout the various pass-bands whether energy supplied to them is shared equally by two filters or not. This circuit arrangement has been adopted for combining the group filters within a super-group and the super-group filters for one coaxial pair.

As a matter more perhaps of academic interest than of practical importance, it may be pointed out that a resistance network could be used instead of the hybrid transformer. Referring to Fig. **5**, the three resistances R, together with the impedance of the common

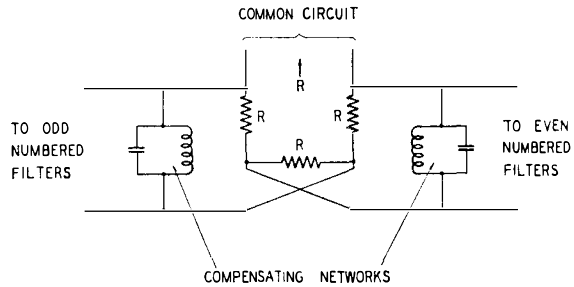


FIG. **5**.—COMBINING CIRCUIT USING RESISTANCES.

circuit, assumed to be resistive, form a balanced Wheatstone Bridge, with the odd-numbered filters across one diagonal and the even across the other. Since the bridge is balanced it is easy to see that variations in the impedance presented by one set of filters would not affect the transmission between the other set of filters and the common circuit. The loss would be 6 db., however, instead of 3 db., owing to the extra resistors that have been introduced.

The impedance presented by any one of the three pairs of terminals of the resistance network would be R if the other two pairs were connected to circuits of that impedance. The circuit would therefore be satisfactory from the point of view of matching impedances. Apart from the question of increased loss the resistance network does, however, suffer from the disadvantage that, unless transformers are added, it cannot be used with unbalanced circuits, neither can it be used with balanced circuits in which longitudinal currents are present.

Group Working on 12-Circuit Carrier Cables

A field trial is in course of preparation to examine the possibilities of working more than 12 channels on each pair in 12-circuit carrier cables. The London-Cambridge route has been selected as being the most convenient, particularly from the point of view of power supplies for intermediate repeater stations.

The 12-circuit carrier equipment to be installed will be "group-modulated" so that one group occupies the range 64 to 112 kc/s, and another occupies the range 112 to 160 kc/s, and these together with a group occupying the normal range of 12 to 60 kc/s will, if the trial proves successful, be transmitted together over the cable.

The existing distant-end cross-talk balancing huts (midway between the repeater stations) will be used as additional repeater stations due to the higher attenuations involved at these frequencies. Two pairs, at least, in each cable will be equipped.

Additional distant-end cross-talk balancing will be required, since the number of repeater sections on the route for these circuits is being doubled, and frequencies considerably higher than normal will be used. The normal amplifiers will also require to be replaced by others which will pass the frequency band 12 to 160 kc/s at least. The circuits will be arranged so that in the event of failure of any part of the experimental equipment, 12-circuit working can rapidly be resorted to.

E. M. R.

The Localisation of Small Leaks in the Underground Transmission Line System at Cooling Radio Station

U.D.C. 621.315.212 : 621.315.221
621.315.23 : 636.67.088

L. L. HALL ; H. S. LLOYD ; C. E. RICHARDS

**" I counted seven and seventy stenches
All well defined, and several stinks."**
—*Coleridge.*

Introduction.

THE construction of a new Post Office radio receiving station at Cooling Marshes, involving the laying underground of approximately 16 miles of concentric transmission line, has necessitated the evolution of a method for the location of small leaks in the transmission line sheathing. To enable the various problems which were encountered to be appreciated a general description of the site and plant layout will be given.

The method of reception to be adopted at this station requires the use of 16 similar aerials, erected over a flat and wet site, each aerial being provided with its own transmission line. The aerials, which are of the rhombic type, were erected in a straight line at 200 m. intervals, so that the whole aerial system extends over a distance of approximately two miles. The station building is located at the rear end of this line, and the transmission lines from the aerials are laid underground along the centre line of the aerial system, back to the station building. The transmission lines were laid side by side in the bottom of a trench which was on the average 2 ft. 3 in. deep, so that starting from the forward end of the aerial system the number of lines steadily increased from one to sixteen.

The requirement that the site should be flat and wet limited the choice of sites to marshes, and this brought various constructional difficulties in its train. The fact that the water-level on this site could reach ground-surface-level, and the necessity for maintaining the lengths of the lines constant irrespective of temperature variations, called for the adoption of special means for the jointing and anchoring of the lines.

As has been mentioned previously, the transmission lines are of the concentric tube type, consisting of high-grade copper tubing, $\frac{5}{8}$ in. and 2 in. diameter for core and sheath, respectively. The tubing was supplied in lengths varying from 16 to 20 ft., and the construction of the 16 miles of line involved the making of some 4,500 joints in each of the core and sheath. Obviously, these joints had to be watertight, and accordingly, special jointing-sleeves of the capillary soldered type were employed. Since the length of the lines had to be maintained constant, the standard jointing-sleeve, as normally supplied by the manufacturers, was modified, and an additional radial flange was provided to increase the earth fixation of the tubes.

It should be mentioned that at the average depth of 2 ft. 3 in. at which the pipes were laid, the soil consisted of very soft wet clay, so that the adhesion of the soil to the sheath could not be relied upon to restrain completely the tendency to variation in length of the line due to seasonal temperature changes. Also, it was thought that there might be some danger of different expansion between the core and the sheath, and accordingly special means to prevent this were adopted. The core was maintained concentric with the sheath by simple three-legged spacing insulators of high-grade ceramic material fixed to the core at 2-ft. intervals, but at each joint, a special insulator was employed which fulfilled the dual function of maintaining the concentricity of core and sheath and restraining differential expansion.

One end of each length of sheathing was provided with three slots, and the special insulator was provided with a projection on the end of each of its three arms, which fitted into the slots in the sheath. The bore of this insulator was metallised with a deposit of copper on silver, to permit the ceramic insulator to be soldered actually to the copper core of the line. Thus the insulator was fixed to both core and sheath, and was strong enough in itself to retain any differential repression between the copper tubes.

It will be appreciated that this insulator lay inside the jointing-sleeve ; and further, owing to the bulk of the insulator, special care had to be taken with temperature changes such as would be applied when soldering the jointing-flanges to the sheath. It was, in fact, found necessary to heat the radial flange first, so that the heat would be gradually conducted through the body of the sleeve and thence to the sheath and insulator.

The same difficulty applied in soldering the core to the insulator. Further, the type of flux used had to be as nearly non-corrosive as possible, consistent with ease and certainty of soldering, since, when the joint had been made, there was no possibility of cleaning off surplus flux. Both of these limitations militated against the ease and certainty of making a perfect soldered joint and, in consequence, when air pressure was applied to the lines it was found that some leaks existed.

It should be mentioned that the work of jointing and laying the transmission line was carried out under somewhat adverse circumstances ; the work had to be completed during the summer period owing to the abnormal site conditions, and also it was not permissible to keep a long length of trench open. The usual method of testing for leaks was therefore not possible. This was not at the time considered a serious matter because the special nature of the jointing flange made the possibility of leakage remote. The position, then, when the leaks become apparent, was that the pipes were laid and the trench filled in, and some method had to be devised for locating such leaks which were of the order of very small pinholes.

FIG. 1.—" I THINK THERE IS SOMETHING DOWN HERE ! "

Methods Available for Detecting Leaks.

A very usual method of locating leaks on a completed air line is to fix a series of pressure gauges along the line and measure the drop in pressure at various points. This method could not be used since the minute leaks which were known to exist could cause no appreciable drop along a line of such large cross-section. In consequence, an attempt was made to adapt the listening rod technique used by the water companies to detect leaks in their mains. The listening rod was pushed into the ground at close intervals, and it was hoped that any near-by air escape would be heard. Experienced men in the water companies use the method quite successfully, but, due to different conditions or to lack of experience, it failed to detect the leaks.

The only method which seemed to offer any hope was to pump into the transmission lines a quantity of gas having a very distinctive and powerful smell. This gas would, of course, escape from the line at various leaks and could then, under favourable circumstances, be detected by a man walking along the line. Now although chemists are generally believed to have an untold number of smells on tap, the problem of finding a suitable one was not easy. The gas itself had to be harmless to the materials used in the construction of the lines and be insoluble in water. It had also to be non-poisonous to animal life. An early thought was to use one of the tear gases which are now available in ample amounts. It was felt, however, that the use of such a gas would invite staff trouble. Finally it was decided to use amyl mercaptan, which is a sulphur compound derived from amyl alcohol. Mercaptans, as a class, are very evil-smelling substances, and are mainly to be found in certain supplies of mineral oil. In the course of refining these oils mercaptans must be removed.

In Europe (and in particular in this country) amyl mercaptan has no commercial use, and is in consequence almost a chemical curiosity. In the United States, however, where natural gas is distributed for domestic purposes, amyl mercaptan is widely used to give a recognisable smell to this otherwise odourless gas. Arrangements were therefore made for a supply to be obtained from America, but while this was on the way there remained the urgent problem of the leaks at Cooling. It was decided that if possible some tests should be made before the supply of odorant could arrive.

There are two ways in which any chemical can be obtained. It can be purchased or it can be made. An attempt was made to purchase amyl mercaptan in this country. The usual laboratory suppliers and a wide selection of manufacturing chemists were tried in vain. Then two of our British motor spirit companies were really helpful ; one gave a small quantity from its meagre laboratory stock, and the other, in addition to knowing where another small amount was available, was able to refer us to a new way of preparing the compound.

When all the available material had been purchased there was still insufficient to make a practical trial at Cooling possible, and a further amount was prepared in the laboratory at Dollis Hill.

It will not surprise anyone familiar with the preparation of organic compounds that the early attempts were not completely successful. The chemical literature gives very little practical help in the matter and there were one or two exciting moments. Enough was, however, prepared to add to the amount already available and make a test possible. There will be many at Dollis Hill who will long remember the smell emanating from the chemical laboratory.

A carburetting device was made so that air from a compressor could be pumped through glass wool

FIG. 2.—" SEEK IT OUT BOY ! "

Fig. 3.—"Oh Yes, Quite Certain About It!"

problem, absolutely bristling with difficulties. There was no precedent of any kind to work on and no literature to consult. After due consideration of the problem and some preliminary trials it was decided to concentrate entirely on a particularly keen scenting and experienced Labrador dog who had previously been trained as a gun-dog; he had also been used as a bloodhound, as a tracker of the "clean heel."* A further accomplishment he had mastered was that of a liaison messenger and carrier in daylight and dark for police and army purposes. With a dog as versatile as this it was felt that some measure of success might be obtained. The matter was, however, very urgent, and at first the chances did not seem bright.

soaked in mercaptan, and thus fill the pipe-line with strong-smelling gas. The first test was made on February 10th and pumping of the odorised air was started at about 11.30, only a few of the shorter tubes being used. After 90 minutes' pumping the party moved off slowly along the line, keeping slightly to leeward and sniffing the air gently. The joints up to the first pole were tested and found good, and it was also checked that the gas had reached the transformer box at the top of the pole. Nothing unusual was found until the middle of the first field (i.e. between poles 1 and 2) was reached. There a faint smell was noticed in the air, and by smelling carefully along the broken earth over the pipe the spot where the smell was strongest was determined. The pipes were uncovered and a small leak was found. The leak was not measured but was in the order of 1 cu. ft. per hour. Exploration was continued for another two fields but no further leaks were detected. It may be added that continual sniffing in a cold breeze seems to freeze the nostrils and make them either really or apparently insensitive.

Introduction of a Dog.

Even before the above-mentioned test was made it had seemed obvious that a man traversing a two-mile length of buried pipe and searching for a smell would be at a great disadvantage, and that if a dog, having a much more sensitive nose, could be trained to search for a "non-game" smell and to give notice when he found it, the chances of finding the leaks would be greatly increased. (There was no record of any such thing having been attempted before, though a story had been heard that something of the kind had been tried in Denmark. At the time it was not known whether this was just a good story or if it was true.) Attempts were therefore made to train a dog to follow the scent of amyl mercaptan.

The training of a dog for such a task represented an entirely new

The Labrador, "Rex of Ware," was first of all familiarised with the smell by several days' intimacy with it, until he was fairly sure of it and could detect the very faintest whiff which was almost undiscernable to the human nose. Continuing the intensive training and burying pieces of meat close to the scented spots (out of doors), the dog was induced to dig whenever he caught the faintest trace of the smell.

When the dog was considered by its trainer to be proficient, a demonstration was given at Dollis Hill. A lead pipe 50 yds. long and having five holes in it was buried across the Construction Park, and air saturated with amyl mercaptan was pumped into it from one end. The dog was brought up-wind to the Park and then allowed to run free. He at once made for the spot where the largest leak was buried, and commenced to dig right on the spot. With some persuasion he found three other leaks, but did not find the fifth and weakest. He also located the

*"Clean-heel" tracking is the type necessary for criminal work, i.e. the dog must be able to track a person by his natural scent and without the aid of any artificial odour.

Fig. 4.—"Audited and Found Correct!"

gassing plant. The performance was impressive, not because the dog could smell the gas (we could all do that), but that he could recognise it and dig at the right spot. The test was actually made more difficult because the wind was blowing right down the line from the largest leak (and the gassing plant) to the smallest. Consequently, so long as the dog was on the line at all he could always get a stronger scent up the line and wanted to go back there instead of sticking to the weaker spots.

A few days after this the dog was taken to Cooling and given a trial there. Gassing on all the tubes was started at 10 a.m., and the first discovery was that of three leaks in the apparatus room, which rapidly became almost uninhabitable. At 1 o'clock the party left with the dog, who was on a long lead (about 10 yards). Almost at once he started to dig about 30 yards from where the pipes enter the ground. He was rewarded with a piece of meat and taken along the line. A digging party was left to uncover the pipes and determine whether there actually was a leak or not. A leak was found. On the rest of the journey the dog made eleven more finds, seven of them being good and one being an old one which had been cleared a few days earlier; the smell had evidently persisted in the ground, and although changed to the human nose had retained its character sufficiently to be identified by the dog.

At the far end of the cable line he made three false locations, but this is not to be regarded so much a fault in the dog as evidence of over-eagerness on the part of those with him, who were disposed to accept any perfunctory scratching as a location. It was found that, when tired, the dog could by strong urging be induced to dig. However, the day's bag of eight good locations spread over a mile was exceedingly good.

A fortnight later a further test was made at which the dog only made two locations, both good. At one place where it was felt certain there was a leak the dog was strongly urged and then made a half-hearted attempt at digging. The pipes were uncovered and no leak was found.

From the experience gained in this work it appears that too great a length of pipe or cable should not be surveyed at one session. It seems essential that, as the scent is not a natural or "game" one, the dog should not be asked to concentrate his attention when feeling tired. Incidentally, it should also be pointed out that Cooling Marshes are used for sheep and cattle grazing, and they must be absolutely alive with animal scents which would normally interest a dog. "Rex of Ware" came through his four-mile trip each time without taking any notice of sheep, cattle, dogs or horses. At the end of a tiring day he showed that he was still a normal dog by joining enthusiastically in a rat hunt.

The illustrations show four stages in the detection of a leak.

Book Reviews

"Electron Optics in Television." I. G. Maloff and D. W. Epstein. 299 pp. 197 Ill. McGraw-Hill. 21s.

During the last few years remarkable advances have been made in cathode ray tubes. The discovery of methods of controlling electron streams to bring them to a sharp focus or to maintain them in accurately parallel paths has been of immense importance in facilitating the development of television to its present stage of perfection.

A number of articles and papers have appeared on this subject, but they have been few, considering its novelty and importance, and a reliable text book on this new extension of the art is welcomed. The authors point out that the book should not be considered as an exhaustive treatment of the subject but rather an account of that part of it with which they have had first hand experience at the Research Laboratories of the R.C.A. Manufacturing Co. Inc. In spite of their modest disclaimer, however, the ground is covered very comprehensively. The book is divided into three sections; an introduction of about 40 pages describes the fundamental principles of television, and presents a brief description of a complete cathode ray television system, and a few applications of electron optics.

The main body of the book is divided into two parts. In Part I the theory of electron emission, and electron optics is developed. Part II deals with the problems encountered in designing tubes capable of producing satisfactory television. In this section are included several approximate methods of solving non-linear circuit problems connected with the design of apparatus associated with the television cathode ray tube. As might be expected Part I is largely pure physics, and covers electron emission, the analogy between electron optics and light, the motion of electrons in electrostatic fields, electrostatics and magnetostatic lenses. Part II deals with the electron gun, luminescent screens, classification, ruling and characteristics of cathode ray tubes, accessories such as scanning oscillators and impulse generators, while a final chapter is devoted to vacuum practice. Enough has been said to indicate that this book is likely to be useful to all who have to work with cathode ray tubes.

A. J. G.

"Accumulator Charging, Maintenance and Repair," (Sixth edition). W. S. Ibbetson, B.Sc., A.M.I.E.E. 161 pp. 42 Ill. Pitman. 4s. 6d.

The main changes between the sixth edition of this book and the fifth are an additional shilling in the purchase price and an additional ten pages of text dealing with 6 V and 12 V batteries for cars, the constant potential method of charging, electric vehicle batteries, and additional questions set at City & Guilds examination for motor vehicle electricians. Otherwise the fifth and sixth volumes are almost identical and even the printer's errors have been perpetuated.

It follows that the main points of criticism and praise given in the review of the fifth edition (*P.O.E.E.J.*, Vol. 29, p. 337) remain unchanged, namely, that despite numerous small blemishes the book contains much sound advice on the upkeep of secondary cells and should be of considerable value to the layman who takes an interest in the welfare of his car, radio or house lighting battery, and especially to the garage proprietor or wireless dealer who undertakes the charging and maintenance of secondary cells.

H. L.

Calculation of Great Circle Bearings

F. ADDEY, B.Sc., F.R.A.S., M.I.E.E.

The author develops a formula which can be used in either the Northern or Southern hemisphere for the calculation of great circle bearings. The application of this formula reduces considerably the calculations usually made in ascertaining this information.

IN determining the lay-out of a directional aerial system, and also in connection with wireless direction finding work, it is necessary to be able to forecast the most probable direction on the surface of the earth of the path which will be followed by wireless waves in passing between the station concerned and one or more distant stations. These paths are great circles, so that the problem is to find the direction, at the station concerned, of the great circle which passes through that station and the distant station.

In the methods published up to the present for obtaining these directions, or "great circle bearings" as they are called, either the distance between the two stations is first calculated, and the bearing then obtained by a formula involving this distance, or else the bearings of either station from the other are simultaneously found. Nearly always, however, it is only the bearing of the distant station from the home station which is required, a knowledge of the distance between the stations or of the bearing of the home station from the distant station being superfluous.

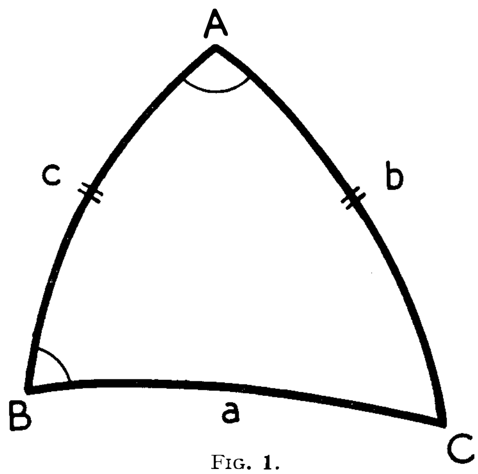


FIG. 1.

In recent years the extensive use of directional aerial systems for transmission and reception, and the development of direction finding stations and of radio beacons, has made necessary frequent computation of these bearings, and any shortening of the calculations required would be an advantage. The method described gives directly the bearing of the distant station from the home station, and is shorter than the other methods mentioned.

In the spherical triangle ABC, Fig. 1, we have:

$$\cos b = \cos c.\cos a + \sin c.\sin a.\cos B \quad \ldots\ldots\ldots\ldots(1)$$

(This is the fundamental formula in spherical trigonometry. The proof can be found in any text-book on the subject. The reader is reminded that the sides of a spherical triangle are expressed in angular measure).

Also:

$$\cos a = \cos b.\cos c + \sin b.\sin c.\cos A \quad \ldots\ldots\ldots\ldots(2)$$

Substituting in equation (1) the value of cos a given by equation (2) we obtain:

$$\cos b = \cos c\,(\cos b.\cos c + \sin b.\sin c.\cos A) + \sin c.\sin a.\cos B$$

$$\cos b = \cos b.\cos^2 c + \cos c.\sin b.\sin c.\cos A + \sin c.\sin a.\cos B$$

$$\cos b\,(1 - \cos^2 c) = \cos c.\sin b.\sin c.\cos A + \sin c.\sin a.\cos B$$

$$\cos b.\sin^2 c = \cos c.\sin b.\sin c.\cos A + \sin c.\sin a.\cos B$$

Dividing each side by sin b. sin c, we obtain:

$$\cot b.\sin c = \cos c.\cos A + \frac{\sin a}{\sin b}.\cos B \quad \ldots\ldots\ldots(3)$$

In a spherical triangle the sines of the sides are proportional to the sines of the opposite angles. Therefore:

$$\frac{\sin a}{\sin b} = \frac{\sin A}{\sin B}.$$

Substituting this for $\frac{\sin a}{\sin b}$ in equation (3), we obtain:

$$\cot b.\sin c = \cos c.\cos A + \frac{\sin A}{\sin B}.\cos B$$

$$\cot b.\sin c = \cos c.\cos A + \sin A.\cot B$$

Therefore:

$$\cos c.\cos A = \sin c.\cot b - \sin A \cot B \quad \ldots\ldots\ldots(4)$$

This formula, called the "four parts formula," can easily be memorised thus:

Call c and A the "inner side" and "inner angle" respectively, and b and B the "other side" and "other angle" respectively. The formula can then be expressed:

cos (inner side). cos (inner angle)
= sin (inner side). cot (other side)
— sin (inner angle). cot (other angle).

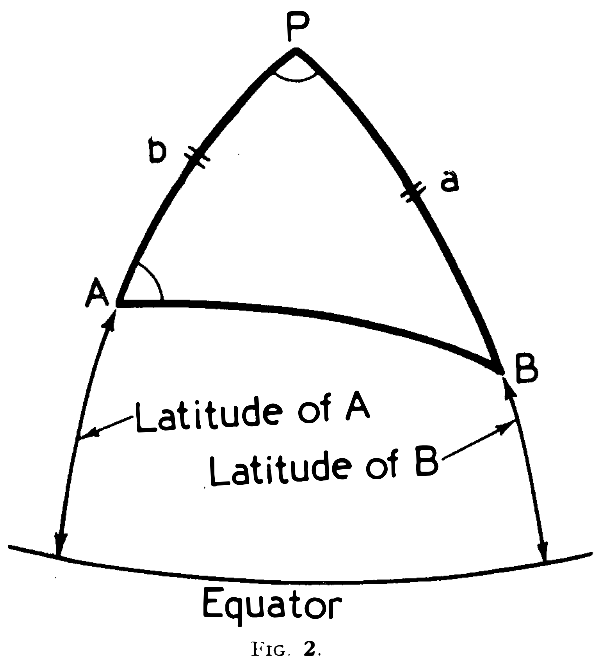


FIG. 2.

Now to apply this formula to the problem in question. Let A and B, Fig. **2**, be two stations in the northern hemisphere, and P the pole. It is required to find the direction at A of the great circle joining A to B, or the bearing of B from A. Bearings are expressed by the angle made by this great circle with the north-south line through the station from which the bearing is taken, this angle being measured from north through east, that is, in the clockwise direction. Bearings measured in this manner are called " true bearings." Thus the true bearing of Station B from Station A is the angle PAB, or A.

In the spherical triangle PAB we have, by the four parts formula, equation (4) :

$$\cos b . \cos P = \sin b . \cot a - \sin P . \cot A \quad \ldots\ldots\ldots (5)$$

Now $b = 90° - \text{lat A}$ and $a = 90° - \text{lat B}$.

Therefore :

$$\left.\begin{aligned} \cos b &= \sin \text{lat A.} \\ \sin b &= \cos \text{lat A.} \\ \cot a &= \tan \text{lat B.} \end{aligned}\right\} \quad \ldots\ldots\ldots\ldots\ldots (6)$$

Also $P = \text{long A} \sim \text{long B}$. This is written " d long," the difference in longitude between A and B.

Thus equation (5) becomes :

$$\sin \text{lat A} . \cos (\text{d. long}) = \cos \text{lat A} . \tan \text{lat B} - \sin (\text{d. long}) . \cot A$$

Therefore :

$$\cot A = \frac{\cos \text{lat A} . \tan \text{lat B} - \sin \text{lat A} . \cos (\text{d. long})}{\sin (\text{d. long})}$$

or :

$$\cot A = \cos \text{lat A} . \tan \text{lat B} . \operatorname{cosec} (\text{d. long}) - \sin \text{lat A} . \cot (\text{d. long}) \quad \ldots\ldots\ldots\ldots (7)$$

Notes.

If cot A be +, A is between 0° and 90°
If cot A be −, A is between 90° and 180°
If B be to the east of A (d. long E), the true bearing of B from A, i.e. measured from N through E, is A.
If B be to the west of A (d. long W), the true bearing of B from A is 360° − A.

In the foregoing investigation it has been assumed that the stations A and B are both in the northern hemisphere. The formula is, however, also applicable when either or both of the stations are in the southern hemisphere, if the convention be adopted that southern latitudes are called negative.

If B, Fig. **3**, be in the southern hemisphere, and " lat B " denote the magnitude of the latitude of B, then $a = 90° +$ " lat B."

Therefore :

$$\begin{aligned} \cot a &= \cot (90° + \text{“ lat B ”}) \\ &= - \tan \text{“ lat B ”} \\ &= \tan (- \text{“ lat B ”}) \end{aligned}$$

Similarly, if A be in the southern hemisphere, $b = 90° +$ " lat A ".

Therefore :

$$\begin{aligned} \cos b &= \cos (90° + \text{“lat A”}) \\ &= - \sin \text{“lat A”} \\ &= \sin (- \text{“lat A”}). \end{aligned}$$

and :

$$\begin{aligned} \sin b &= \sin (90° + \text{“lat A”}) \\ &= \cos \text{“lat A”} \\ &= \cos (- \text{“lat A”}). \end{aligned}$$

Thus, when the appropriate signs are prefixed to the magnitudes of the latitudes, equations (6) hold good wherever A and B may be. Therefore equation (7), which is obtained by the substitution in equation (5) of the values given by equations (6), also holds good universally.

Two examples of the method just described are given below. It will be seen that the working can be set out very compactly.

The small n's written against certain of the logarithms in the second example are indications that these logarithms are those of negative numbers.

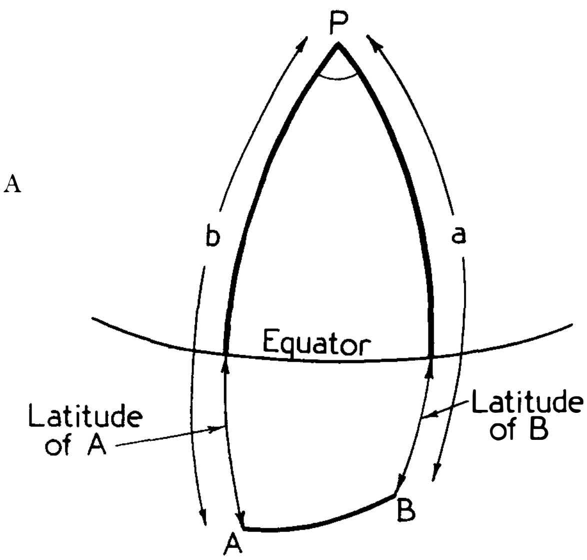


FIG. 3.

Examples.

	Lat.	Long
(1) Bearing from Lands End Radio	50° 07′ N.	5° 40′ W.
of Ushant :	40° 27′ N.	5° 05′ W.
	d. long :	0° 35′ E.

log cos 50° 07′ = 9·8070114
log tan 48° 27′ = 10·0524280
log cosec 0° 35′ = 11·9922133
1·8516527 = log of 71·0645 (a)
log sin 50° 07′ = 9·8849945
log cot 0° 35′ = 11·9921908
1·8771853 = log of 75·3677 (b)
(a − b) = − 4.3032
= cot of (180° − 13° 05′).
Therefore : A = 166° 55′

Since d. long is E, the true bearing of Ushant from Lands End is 166° 55′.

′(2) Bearing

from London......	51° 30′·5 N.	0° 05′·75 W.
of Perth, Australia	31° 57′·5 S.	115° 52′·75 E.
	d.long :	115° 58′·5 E.

log cos 51° 30′·5 = 9·7940701
log tan (−31° 57′·5) = 9·7950862 n
log cosec 115° 58′·5 = 10·0462474

9·6354037 n

= log of − 0·431920..(a)

log sin 51° 30′·5 = 9·8935946
log cot 115° 58′·5 = 9·6877006 n

9·5812952 n

= log of − 0·381325.....(b)

(a−b) = −0·050595

= cot of (180° − 87° 06′·22).

Therefore : A = 92° 53′·78

Since d. long is E, the true bearing of Perth from London is 92° 53′·78.

Notes and Comments

Birthday Honours

The Board offers its congratulations to the following members of the Engineering Staff on whom honours have been conferred in the Birthday Honours list.

To be Members of the Most Excellent Order of the British Empire :

Mr. W. C. Burns, Motor Transport Officer Class I, E.-in-C.O.
Company Sergeant-Major F. O. Creighton, Skilled Workman Class I, London.
Company Sergeant-Major L. A. Whittingham, Skilled Workman Class I, London.

To be awarded the Medal of the Most Excellent Order of the British Empire :

Mr. A. E. Twycross, Chief Inspector, Nottingham.
Mr. A. P. Barker, Skilled Workman Class I, Uxbridge.

Board of Editors

Readers will be interested to learn that Mr. A. J. Gill, after an absence of a year, has returned to the Board of Editors as Chairman, to fill the vacancy arising from the promotion of Mr. P. J. Ridd. The list of members of the Board as now constituted is given on page 158.

Dr. L. F. Morehouse

The Board of Editors has heard with regret that Dr. L. F. Morehouse, technical representative of the American Telephone & Telegraph Company and Bell Laboratories in Europe since 1935, is returning from this country to the United States at the end of June on the conclusion of his active service with the Bell organisation.

Dr. Morehouse first visited this country in 1906 to 1909 as Transmission Engineer of the Western Electric Company, and was associated with engineers of the National Telephone Company and Post Office on the introduction of iron core loading coils into this country. Until his return in 1935, he was largely concerned with development work, especially in the field of automatic telephony, in the Bell Laboratories.

Since 1935, he has not only represented his Administration in Europe, but has acted as a very efficient liaison between the Bell organisation and the Post Office. The relations between these two Administrations are now much closer than ever before and his wealth of experience combined with a very attractive personality have contributed very materially to this happy position. His many friends in this country will wish him and his family bon voyage and much health and happiness in the years to come.

Dr. Morehouse is succeeded by Mr. C. W. Green who has already arrived in London. To him the Board, on behalf of its readers, extends a cordial welcome and hopes that his stay in this country will be profitable and enjoyable.

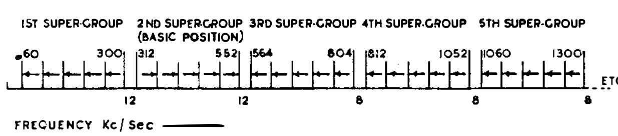
Errata

It is regretted that there are errors in the article entitled Comité Consultatif International Téléphonique ; Meeting of the Sub-Committees, London, December, 1938, published in the April issue.

Page 53, last paragraph, 5th and 6th lines, should read :—One super-group comprising 5 groups is shown in the . . .

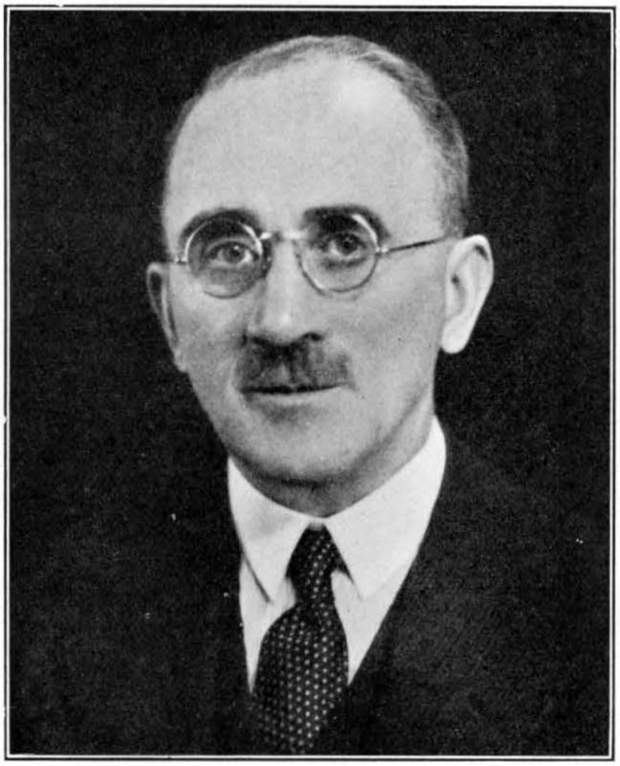
Page 54. The following diagram is the correct version of Fig. 3.

Page 54, third paragraph, line 6, should read :— 1116, 1364, 1612 . . . etc. kc/s. These are the 9th, 11th, 13th . . .



Retirement of Sir George Lee, O.B.E., M.C., B.Sc., M.I.E.E.

Sir George Lee, O.B.E., M.C., B.Sc., M.I.E.E., who retired from the position of Engineer-in-Chief to the Post Office on May 31st, was himself the son of a Post Office Engineer. In the early part of his career, he was very closely associated with the development and introduction of loading coils. Later, he was concerned with improvements in the design and testing of cables, particularly submarine telephone cables. In 1908, Sir George left the Engineer-in-Chief's Office for Darlington and in the following year took charge of the Bolton Engineering Section. In 1912 he returned to Headquarters as an Assistant Staff Engineer and was engaged principally on problems of telephone transmission.



During the war he served with the Royal Engineers (Signal Section) in France and Belgium. After a time he took charge of No. 4 Telegraph Construction Company, and later became O.C., G.H.Q. Signal Area. For a short time after the war, Sir George Lee was in the Construction Section, but soon joined the Radio Section in which he served for many years. He played a prominent part in the design of the radio station at Rugby and later in the successful development of long distance radio telephony which has given us telephone connection with the United States and the Dominions.

Sir George Lee was appointed Engineer-in-Chief in December, 1931. At this time the Post Office was experiencing the effects of the industrial depression, but in a few years revival of trade and reduction of rates resulted in a very great increase of work in all branches of the work of the Engineering Department. During most of Sir George's tenure of his office, therefore, he has been faced with the numerous problems of administration arising from this situation.

Sir George Lee has always been active in the promotion of co-operation between this country and others in the field of telecommunications and has led the British delegation at many international conferences on these matters. In 1928 he was appointed Chairman of the Radio Research Board and still holds that position. His wide knowledge and experience of radio engineering received further recognition in the same year when he was elected Vice-President of the Institute of Radio Engineers of America, an honour which he was the first Englishman to hold. He was awarded this year the Medal of Honour of the Institute. This medal is given in recognition of distinguished service in radio communication, and is awarded to one who has been responsible for an important advance in the science or art of radio communication.

He has been an active member of the Institution of Electrical Engineers, having been Chairman of the Wireless Section in 1927 and a member of the Council from 1931 to the present time. He held the high office of President of the Institution in the year 1937-38.

He was awarded the honour of Knighthood in January, 1937.

Although Sir George Lee's activities have covered the whole of the telecommunications field, he will perhaps be remembered chiefly for his work in the establishment of transatlantic telephony. While engaged in the experiments which preceded this development, he was naturally brought into close contact with the staff of the American Telephone and Telegraph Company. He has since helped to maintain the closest liaison between the Post Office and the American organisation, with the result that there is now a very free interchange of information and experience between the two administrations.

Sir George Lee will be specially remembered, too, for his deep interest in the development of carrier telephony, and he was one of the first to appreciate the economies which could be made by a forward policy in the use of multi-circuit working. Realising that intensive telephone development can come only from the provision of service at a popular figure, Sir George has, in recent years, given considerable attention to means for cheapening the telephone service. To this end he has encouraged investigation into all possible means of effecting reduction in capital or running costs.

Notwithstanding the many pre-occupations of his position, Sir George Lee has not neglected the human aspect of his task. He has taken a keen interest in the social activities of the staff under his control, and occupied the position of President of the Engineer-in-Chief's Office Social and Sports Club. In his retirement he carries with him the good wishes, not only of his large staff, but of numerous others who have enjoyed the privilege of association with him.

A. S. A.

Col. A. S. Angwin, D.S.O., M.C., T.D., M.I.E.E.

Colonel A. S. Angwin, D.S.O., M.C., T.D., M.I E.E., who succeeds Sir George Lee as Engineer-in-Chief of the Post Office, was educated at the East London College (now known as Queen Mary College) and received his practical engineering training with Messrs. Yarrow & Co., Ltd., Engineers and Shipbuilders. He joined the Post Office Engineering Department in 1906 and shortly after was transferred to Glasgow. Here he gained a wide experience in all phases of district work and made a special study of underground construction—a subject which in those days was a new development.

When the Territorial Force was inaugurated he raised the Lowland Division Telegraph Company which was comprised almost entirely of Post Office staff. The unit was mobilised in 1914 and formed into the 52nd Divisional Signal Company with Major Angwin as Officer-in-Command. He served through the war with the unit in Gallipoli, Egypt, Palestine, and France and was awarded the M.C. and the D.S.O. After the war he commanded the 44th Home Counties Divisional Signal Company until 1927 when he was awarded the T.D. (20 years' service).

After the war he was brought to London to join the Wireless Section of the Engineer-in-Chief's Office, which was then in a state of rapid expansion. He took a large part in the design and construction of the Leafield, Cairo, and Rugby radio stations and in the inauguration of the transatlantic telephone service.

He was promoted to Executive Engineer in 1920, Assistant Staff Engineer in 1925 and Staff Engineer in 1928. Under his direction the Radio Section developed equipment for short-wave radio telephony and built up the multiplicity of overseas radio services which has given this country a predominating position in world telephony.

In 1933 he was promoted to Assistant Engineer-in-Chief and in 1935 he was advanced to the post of Deputy Engineer-in-Chief.

Colonel Angwin has taken a large part in international work and as British delegate he attended the Madrid and Cairo Telecommunication Conferences, the Lisbon and Bucharest meetings of the C.C.I.R. and the Lucerne and Montreux European Broadcasting Conferences. His abilities in leadership are so well known and appreciated that when a chairman is required for a subcommittee on a difficult and controversial subject, such as wavelength allocations, Colonel Angwin is usually invited to act in this capacity and he never fails to do so with distinction.

Colonel Angwin takes an interest in the Institution of Electrical Engineers and the Institution of Civil Engineers, and has read papers before both Institutions on telecommunications subjects. He served a term of office as Chairman of the Wireless Section of the Institution of Electrical Engineers and is at present a Member of Council of that Institution.

Among many other activities Colonel Angwin has been a member of the Television Committee since its commencement and he takes a keen technical interest in the development of television.

His appointment as Engineer-in-Chief will be received with satisfaction throughout the Department in the sure knowledge that a worthy successor occupies this important post and that his tenure of office will add distinction and prestige to the Engineering Department.

A. J. G.

P. J. Ridd, M.I.E.E.

Mr. P. J. Ridd, who succeeds Colonel Angwin as Deputy Engineer-in-Chief, served in the National Telephone Company, and from 1907 to the "Transfer" was responsible, under the Metropolitan Electrician, for all exchange construction and subscribers' installation work in the London area. He joined the Post Office as Executive Engineer in the Metropolitan Central District, and from 1915 took charge of the London City Internal Section until 1926, when he was appointed Assistant Staff Engineer in the Research Section. He returned to the London District in 1928 as Assistant Superintending Engineer, when the automatisation of the London exchanges was in its early stages, to take charge of the maintenance of internal and external plant, and in 1932 returned to Headquarters as Staff Engineer of the Construction Section. In January, 1936, he was appointed Deputy Superintending Engineer, London District, and later Chief Regional Engineer, London Region, becoming Assistant Engineer-in-Chief in September, 1936.

Mr. Ridd has represented the Post Office on Committees of the Institution of Electrical Engineers, the British Standards Institution, the City and Guilds of London Institute, and was the chief British delegate at the C.C.I. and I.E.C. Conferences when Publication 42, Graphical Symbols for Weak Current Systems, was revised. He has been chairman of the Board of Editors of the JOURNAL for the past year.

Mr. Ridd has had a long and varied experience in telephone engineering and in his new appointment has the confidence and good wishes of all his colleagues.

J. R.

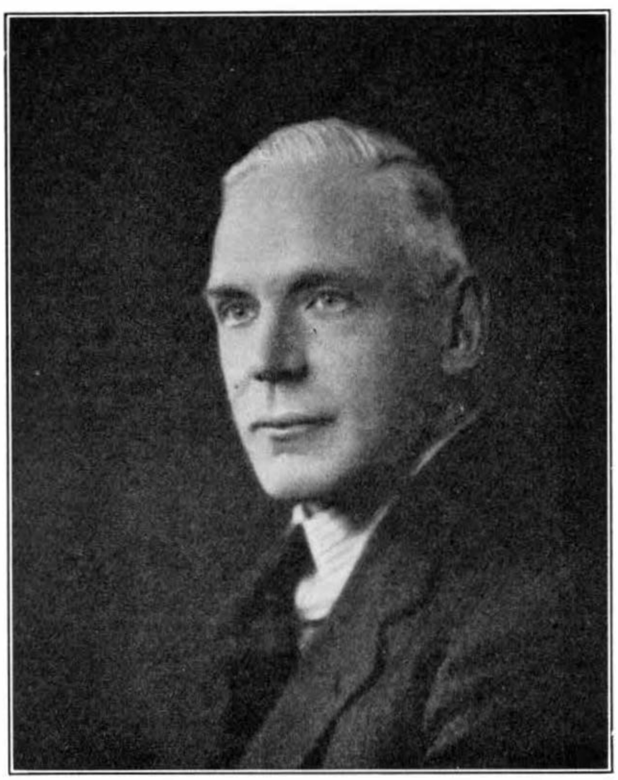
G. F. O'dell, B.Sc., A.K.C., M.I.E.E.

Mr. G. F. O'dell, who became Assistant Engineer-in-Chief on June 1st, 1939, entered the Post Office Engineering Department in October, 1909. After experience in the Willesden Section and Central Telegraph Office Section, he was one of the two engineers selected to go to America for special training in telephony, including automatics. On his return, after fifteen months in America studying all phases of the industry, he was posted to the Telephone Section and engaged on maintenance and construction of automatic exchanges. During the War he served in France and Belgium with the Royal Engineers (No. 5 Telegraph Construction Company), and on his return was again engaged on automatic exchange maintenance, but gave particular attention to the theory and standardisation of trunking, to which his contributions are of international importance.

He was promoted Executive Engineer in March, 1927, and in June, 1932, became Assistant Staff Engineer in charge of development, holding this position during the extension of the trunk demand system, the introduction of the P.O. 3,000 type relay, and the design of Units Auto Nos. 7 and 12. He was promoted Staff Engineer in charge of the Equipment Branch in July, 1935.

Mr. O'dell has taken a great interest in the Institution. He is the author of several I.P.O.E.E. papers and JOURNAL articles and has held many Institution offices. His appointment to Assistant Engineer-in-Chief will afford him the opportunity to apply his varied knowledge and experience in a wider field and is welcomed by his many friends and colleagues.

J. R.



Local Centre Note

North Wales Centre

The sixth meeting of the 1938-1939 session took place in the Assembly Hall of the Technical College, English Bridge, Shrewsbury, on Thursday, March 9th, 1939, at 2.45 p.m.

The Chairman, Mr. H. Faulkner, presided over an attendance of 123 members and visitors, the latter including representatives of the District Managers' staffs at Chester and Gloucester, the traffic staff of the Birmingham Area Manager and representatives of the West Midlands Joint Electricity Authority. The paper before the meeting on this occasion was that by Mr. H. M. Wells, Grad.I.E.E., of the South Eastern District, entitled "Some applications of automatic telephone apparatus outside the field of telecommunications." Mr. Wells gave a brilliant paper with various extensions which proved him master of his subject. The paper was full of interest and, as well as being illustrated with a selection of slides, was covered by practical demonstrations on models of automatic traffic control systems and remote metering apparatus for power stations.

In opening the discussion, Mr. Watkins, Assistant Superintending Engineer, said that the telephone engineer could take pride in the fact that automatic telephone apparatus was now being widely used in other fields of electrical engineering. Several members took the opportunity to discuss the paper and the Chairman closed the discussion speaking on the maintenance aspect of traffic control pillars, comparing such relay sets with our group service boxes. Mr. Wells fully covered all the questions in his reply to the discussion, also giving many other interesting points in connection with the various systems mentioned in the paper.

The meeting then terminated at 4.55 p.m. with a hearty vote of thanks to Mr. Wells, seconded by the assembly in the usual manner, after which members gathered round the exhibits for a closer examination.

The seventh and final meeting of the session took the form of a practical demonstration of the manufacture of "Motor Transport" by one of the Department's chief suppliers, Morris Commercial Cars, Ltd., of Adderley Park Works, Birmingham, who welcomed the centre to see over its works.

Members from all over the North Wales District foregathered at Telephone House, Newhall Street, Birmingham, at 1.30 p.m. to board two 54-seater double deck Corporation buses which had been requisitioned to carry a party of 100 members to Adderley Park, a suburb of Birmingham, for which the buses left at 1.45 p.m. prompt.

Arriving at 2.5 p.m., the party was met by Mr. Cladish, Sales Manager, and was split up into a number of small parties preparatory to touring the works.

A general outline of what was to be seen was first given by Mr. Cladish, after which the parties moved off into the works. Just over two hours later tired, hot and noise-deafened, but still interested, the groups rejoined at the Staff Club to enjoy a delightful tea very kindly provided by the management.

After tea Mr. Cladish spoke of the pleasure of the management in seeing members of the Institution and representatives of one of its customers and hoped that some idea of the building of the Department's vehicles had been gained.

Mr. H. Faulkner, Chairman of the Centre, responded and thanked Lord Nuffield and the management of the Adderley Park Works for the opportunity to see over the works, saying that members would understand our vehicles better for having seen their manufacture. A special vote of thanks was passed to Mr. Cladish and the other guides for their services, which was acclaimed by the party in the usual manner.

The buses picked up the party again at 5.20 p.m. to return to Telephone House, which was reached at 6.45 p.m.

As the demand to go to this meeting was larger than usual, it was necessary to limit the party to 100, and two other parties of a similar number visited the Works on April 25th and 27th, 1939.

This concluded the activities of the Centre for the Session 1938-1939.

Junior Section Notes

Aldershot Centre

During the recent session three interesting debates have been held on the subject "Methods whereby Members could improve on Departmental Methods" in respect of overhead and internal maintenance and construction. They were very interesting and created a good discussion.

There has been a better interest displayed during the past session, which is very pleasing.

Chiltern Centre

At a meeting held at Amersham—presided over by Mr. Allen, Inspector, High Wycombe—it was unanimously agreed that a Junior Centre be formed in the area and that it should be known as "The Chiltern Centre."

The following officers were elected :—

Chairman : F. Sheriff.
Vice-Chairman : E. Sheppard.
Secretary : L. B. Slatter.
Committee : H. J. Trotman, J. W. Arthur, F. G. Bates, L. F. Page, W. Dean and G. Hope.

The meeting was well attended and the Committee are arranging a programme for the forthcoming session which will be announced at a later date.

Gloucester Centre

The attendance at the final meeting held at Gloucester for the 1938/39 session showed that interest in the Centre continues to be fully maintained.

Before the paper was read, officers for the forthcomng session were elected and the retiring Secretary, Mr. F. E. Huckfield, and Treasurer, Mr. S. B. Foote, who had both received recent promotions to Inspectorships, were made life members in recognition of their services.

A very interesting paper on Carrier Telephony was then given by Mr. B. B. Butterworth and, on conclusion, the Sectional Engineer, Mr. H. W. Gifford, addressed the meeting and encouraged members to continue their interest in the Centre.

The papers read during the session were of a high standard and were as follows :—

Local Line Development : R. A. Whitehead.
Electrical Interference to Broadcast Reception : F. E. Huckfield.
First Aid and A.R.P. : J. H. Gale.
Local Line Transmission : W. J. Trimmer, A.M.I.E.E. (member of the Senior Section).
Carrier Telephony : B. B. Butterworth.

Owing to illness, we were unable to hear a paper on fault abatement which was to have been given by Mr. G. E. J. Jacobs, Senior (a member of the Senior Section), and hopes were expressed that Mr. Jacobs would soon make a speedy recovery.

Officers for the 1939/40 session are :—

Chairman : A. J. Hodgson.
Vice-Chairman : C. H. Cecil.
Treasurer : P. F. Noctor.
Secretary : R. R. Hodges.
Committee : J. I. Harrison, K. B. Hodges, R. J. Long, W. G. Powell, J. A. Purveur and A. J. Stiff.

It would be appreciated if anyone wishing to read a paper during the next session would give his name to one of the above officers.

The thanks of the Centre are due to Mr. Cecil for the operation and use of the lantern, which has greatly attributed to the interest of the papers read.

In closing these notes we should like to wish every success to our colleagues at Swindon who have recently opened a Centre. R. R. H.

Huddersfield and Halifax Centre

The first season of the Huddersfield and Halifax Centre was brought to a most successful close on April 1st by a visit to the Manchester Blackfriars auto, trunk and toll exchanges, by 47 members and friends.

This was followed by tea in the Telephone House Café, by kind permission of the Dining Club Committee. The evening was then spent by many members and friends at the Princes Theatre, and elsewhere.

The seven lectures in the 1938-9 programme were fairly well attended and in only one instance was a senior officer called upon for a paper.

The present officers of the Centre thank all members for their support, especially those who kindly came forward to give papers.

It is hoped that all will continue to take an interest in the Centre and help to make the 1939/40 programme even more successful. A. G., J. H. N.

Manchester Centre

The 1938/39 session of the Manchester Centre has not been so successful as previous sessions from the attendance point of view, but has been well up to standard for interesting visits and papers. A total of six meetings and five visits were arranged, but unfortunately two of the visits had to be cancelled, due to causes beyond our control.

At the Annual General Meeting the following officers were elected for the 1939/40 session :—

Chairman : W. Hyde.
Vice-Chairman : J. Pickles.
Secretary : E. G. Owen.
Assistant Secretary : Andrew Jones.
Treasurer : R. R. Gaythorpe.
Librarian : A. Bentley.
Committee : Messrs. Pratt, Potter, Cleary, Brierley, Pauline and Albert Jones.

The debate after the Annual General Meeting was " That this house is of the opinion that the advantages of modern electrical inventions have been offset by the evils which they have produced," which produced a very interesting discussion ; on being put to the meeting the motion was voted on, and was returned with 32 votes for and 12 against.

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 compiling the new session's programme, and would welcome any suggestions or offers of papers from members.

Ryde Centre

Unfortunately, the most noteworthy fact in connection with the first session of this Centre was the marked falling-off in attendances at the later meetings.

For next session it is hoped to arrange a more ambitious programme than was possible last September and to extend the scope of the papers given, by invitations to colleagues outside the Centre, and it is hoped that these efforts will be better rewarded than were those of members who volunteered the papers given last session.

Members expressing dissatisfaction at the continued location of all meetings at Ryde are assured that the possibility of holding some at, say, Newport and Shanklin, will be considered by the Committee at the next meeting. It is pointed out, however, that, from the point of view of transport alone, Ryde is by far the most convenient venue.

For the present, it is desired to urge very strongly the necessity for united and continuous co-operation by all members if the Centre is to continue successfully, and they are reminded that all they are asked to do to ensure this success is to give up one evening monthly to attend the meetings. R. A. Y.

Slough Centre

We can look with pride upon 1938, the year our Centre was born, as being a very successful and interesting start of what we hope will prove to be a worthy Centre of the Junior Section. Our best thanks are due to the officers of the Centre for the excellent arrangements made during the session and to our President, Mr. Mortimer, for the keen interest he has shown in our welfare. The best way to repay this honorary service is for all of us to make new members.

It is important to note that next season's meetings will be held at The New Telephone Exchange, Slough, and it is hoped that the Windsor and Ascot members will continue their support in spite of the journey.

The programme drawn up for next season is a very ambitious one, but the Committee are determined to carry it out. In the meantime, the Committee will be engaged in arranging certain visits to places of interest and they hope all members will give their support to this venture.

Applications for membership of the Centre should be sent to Mr. S. W. Wiltshire, Windsor Exchange.

Southampton Centre

The Annual General Meeting was held at Ogle Road on Thursday, April 13th. The following officers were elected for the 1939/40 session :—

Chairman : C. S. Hale (Inspector).
Vice-Chairman : R. J. White.
Secretary and Treasurer : N. E. Dodridge.
Auditor : R. H. Tucker.
Committee : C. F. Middleton, S. E. Harvey, C. Hislop, F. Couzens, R. J. White, R. Maggs, D. T. Bagley and L. T. Jennings (Inspector) co-opted for East Park Terrace.

The last paper for the 1939 session was read by Mr. E. W. Weaver, Grad.I.E.E. (Assistant Engineer), entitled " The Local Interviewing Board." Mr. Weaver covered his subject from procedure to the objects of the Board and gave an analogy of the ambitious schoolboy and the interviewed. All questions were answered fully.

The programme for 1939/40 will be compiled and circulated as soon as possible. The Committee have in the past arranged the programme to cover the widest range of subjects of interest to the members, while maintaining a high standard.

The fitting, maintenance and construction staffs are cordially invited to join the Junior Section. A visit will be made in due course to a local cinema to inspect the " Talkie " apparatus and general electrical lay-out of a modern cinema. Mr. Maggs will give details later.

Our thanks are due to all members who have supported us during the session, to the Senior Section members who have attended, and particularly to Professor Menzies, Southampton University College, for the loan of projectors and operator. N. E. D.

District Notes

London Region

SEVEN-DIGIT DIALLING FROM TRUNK EXCHANGE

During the past three months there has been considerable activity in the opening of new automatic exchanges and eight such exchanges have been opened. Over 21,000 subscribers have been transferred from manual to automatic working and over 8,000 automatic junctions brought into use. The most notable was the introduction of 7-digit dialling to the London director network from the Trunk Exchange in Faraday Building. The change-over from 4-digit to 7-digit working was spread over four week-ends commencing March 5th. One hundred and thirteen routes, comprising approximately 650 junctions, were changed over, thus giving the traffic staff access to the London network by director outlets from the trunk junction multiple.

The new arrangement will also enable the provincial zone centres to dial direct into the network via the 2 V.F. equipment. Extensive rearrangement of the multiples of the eight large switchrooms, which formed the International and Trunk Exchanges, was necessary to provide :—

(1) Positions for additional director outlets from the multiples ;
(2) Spare provision for 2 V.F. routes to facilitate the change-over to 2 V.F. signalling ;
(3) For the rearrangement of certain outgoing junction routes which have retained a number of 4-digit circuits.

The equipment brought into use as a result of the opening of the Trunk auto. exchange is as follows :—

Manual	1st code selectors	480
	2nd code selectors	1,836
	3rd code selectors	297
	" A " digit selectors	126
	Directors	154

Numerous changes in the positions of circuits in the multiples were necessary prior to and immediately after each stage of the transfer in order that all routes should be available for service by 7 p.m. to meet the demands due to the cheap night rates. It is interesting to note that the following jumper wire was used in connection with the provision of the new equipment and rearrangement of the existing multiple jack fields :—

32 miles of 4-wire jumper ;
61 miles of 3-wire and single wire jumper.

Approximately 27 miles of 4-wire jumper were recovered. The number of labels recovered and replaced during the four week-ends was 70,000 and the number of groups of circuits on which free line signal rearrangements were concerned was 118.

Each stage of the transfer was effected without any hitch and without any interruptions to service, which speaks well of the excellent co-operation which existed between the engineering and traffic staffs concerned.

HODDESDON NON-DIRECTOR AUTOMATIC EXCHANGE

This exchange was installed by Messrs. Standard Telephones & Cables, Ltd., with initial capacity of 1,200 lines, ultimate 2,300. Eight hundred and fifty subscribers' and 100 junction circuits were transferred from the manual exchange at 1.30 p.m. on March 16th. The manual board is at present located at Tottenham manual exchange and the power plant is of the parallel battery float system. Two batteries of 300 Ah each, connected in parallel, were installed by the Hart Accumulator Company, Ltd., and are charged automatically by two 15 A mercury arc rectifiers under the control of an Ah meter. The provision of a third mercury arc rectifier to cover future developments has been allowed for.

LADBROKE DIRECTOR AUTOMATIC EXCHANGE

This exchange was installed by Messrs. Ericsson Telephones, Ltd., with an initial capacity of 3,600, ultimate 5,000, and is equipped with line finders. At 1.30 p.m. on March 30th 1,073 subscribers at Ladbroke manual exchange (old Park) and 711 subscribers from Willesden were transferred to the new equipment. This exchange has its own manual suite of 15 sleeve control positions to cater for " O " and " TOL " traffic. The power plant is of the divided battery float system, the batteries being supplied by the Chloride Electrical Storage Company. Two motor generators of 100 and 200 A output respectively have been provided and arrangements include provision for a third motor generator when required. Automatic voltage regulators of the carbon pile type are provided for each motor generator for controlling the machine output under floating conditions. The two main batteries are each plated to 800 Ah, with boxes having an ultimate capacity of 1,200 Ah.

Prior to the opening of the exchange it was found that when the battery not on float was being trickle charged an audio frequency E.M.F. was introduced across the exchange discharge leads. The disturbance was due to induction between the trickle charge leads and the exchange discharge busbars despite the fact that the disposition of the leads and busbars was reasonably remote. By rearranging the routes of the leads the induction was reduced to negligible limits.

ALBERT DOCK DIRECTOR AUTOMATIC EXCHANGE

One thousand eight hundred and fifty-seven subscribers were transferred at 1.30 p.m. on April 1st from the manual exchange to the new automatic equipment installed by Messrs. Standard Telephones & Cables, Ltd. The equipment has an initial capacity of 2,400 lines with an ultimate of 5,400, and is of the standard line finder type. The sleeve control manual board of 10 positions is situated in the same building. The power plant is of the divided battery float system and the batteries were supplied by the D.P. Battery Company, Ltd. Initial provision of the machines comprised two motor generators of 100 and 300 A output respectively and provision is made for an additional 300 A machine to cater for future developments. Each machine is provided with an automatic voltage regulator of the moving-coil type and the two main batteries are each plated to 1,200 Ah capacity with boxes having an ultimate capacity of 1,650 Ah.

MARYLAND DIRECTOR AUTOMATIC EXCHANGE

Two thousand nine hundred and fifty-eight subscribers were transferred from the old exchange to the new equipment installed by Messrs. General Electric Company, Ltd., at 1.30 p.m. on April 22nd. The equipment of standard line finder type has initial capacity of 4,000 lines with an ultimate of 6,800. Manual board traffic is dealt with at Advance Bypath Exchange. The power plant is of the divided battery float type, and two motor generators of 100 A and 200 A output respectively are provided with accommodation for a third machine of 200 A at a later date. Each motor generator is provided with an automatic voltage regulator of the carbon pile type to control the machine output under floating conditions. The batteries supplied by D.P. Battery Company, Ltd., are plated to 1,200 Ah with boxes of capacity of 1,650 Ah.

HEADQUARTERS' AUTOMATIC EXCHANGE

The old " Official " P.A.B.X., National 6321, situated in the C.T.O. Building, was replaced by a non-director line finder equipment at 1.30 p.m. on April 29th. The old exchange was of Keith line switch type and was installed in 1912, and the fact that it has given good service over a period of 27 years speaks well for the robustness of the old Strowger equipment, which was among the first of its kind to be installed in this country. The new equipment is housed in the Wood Street Building and is of standard non-director line finder type, manufactured by Messrs. Ericsson Telephones, Ltd. The auto-manual suite is in the same switchroom as those for Metropolitan, National and London Wall and the power supply is obtained from the existing batteries serving these exchanges. The equipment has an initial capacity of 1,600 and ultimate 2,000. One thousand one hundred extensions in the Headquarters' Building, C.T.O., K.E.B., Alder House and other Post Office buildings were transferred, together with 214 junctions and the lines to and from other switchboards in the London area. The code HEA has been brought out on all directors in the London network and 95 junctions are provided from Holborn Tandem exchange to route calls from the public system into the Headquarters' exchange. All extension numbers have 4 figures so that a caller can obtain any extension by dialling HEA plus extension number. If the extension number is not known the manual board can be obtained by dialling HEA1234.

As far as outgoing calls from the exchange are concerned, any number in the director area can be obtained by dialling 7 followed by the 7 digits of the required number. A number of 1- and 2-digit dialling codes are provided to enable extensions on the exchange to obtain other Post Office Departments such as the Accountant General's Department, Dollis Hill Research Station, Mount Pleasant Sorting Office, Cornwall House, Waterloo Bridge House, Faraday Building, Union House, Savings Bank and Stores Department. Special codes have also been allocated for Toll, Trunks, ENG and the Speaking Clock.

It is of interest that the ringing machines are of the new " tone inductor " type and represent the first of their kind to be installed on a permanent basis in the Region. On this type of machine the high speed tone drum which was employed on earlier types of machines is dispensed with and the tones are generated by an inductor. By this means the tones have an improved wave shape and are of much purer quality. The regular machine is fitted with a mains driven synchronous induction motor which ensures constant speed and tone frequency regardless of ringing loads.

VICTORIA DIRECTOR AUTOMATIC EXCHANGE

Six thousand eight hundred and ninety-one subscribers and 2,864 junctions were connected to the new Victoria automatic exchange installed by the General Electric Company, Ltd., at 1.30 p.m. on May 6th. The exchange has a multiple capacity of 10,000 and 7,600 uniselectors have been fitted. The manual exchange was one of the largest in the London area and was of 40 V Peel Connor type installed in 1912. It was notable for the very large amount of C.C.I. equipment. The exchange is situated such that a very large proportion of the incoming traffic is originated at automatic exchanges in the centre of London. There were 24 C.C.I. positions divided into two suites of 12, 1,100 incoming junctions from automatic exchanges having access to these positions. There were 98 " A " positions, including an island suite of 23 with 1,540 outgoing junctions. There were also 11 ordinary " B " positions, 3 S.F.J. and 11 Toll positions equipped with chargeable time indicators.

The power plant at the new exchange is of the divided battery float system and the machine equipment provides for :—

Initial	*Ultimate*
1 motor generator 200 A.	3 motor generators 800 A.
1 motor generator 400 A.	1 motor generator 400 A.

This special grading of machines is due to the gradual development anticipated over a long period and the provision of a second exchange unit in the same building at a later date. It is intended that the 200 A machine should be recovered when the third 800 A machine is installed, and to avoid alterations of piers at this stage an over-size pier has been provided for the 200 A machine.

Two automatic voltage regulators of the moving coil type are provided, one suitable for use with either the 200 A or the 400 A machine, and the other suitable for use with the 800 A machine. Switches are provided for changing from automatic regulator to hand regulator, so arranged that voltage regulator No. 1 may be connected to either the 200 A or the 400 A machine initially and voltage regulator No. 2 may be connected to any of the 800 A machines ultimately. The switches are changed by one transferable handle which can be fitted to or removed from any switch only when in the hand regulator position to prevent more than one machine automatically controlled being in use simultaneously.

The two main batteries installed by the D.P. Battery Company, Ltd., each have a plated capacity of 4,800 Ah with boxes for an ultimate capacity of 8,400 Ah.

KINGSTON DIRECTOR AUTOMATIC EXCHANGE

Five thousand six hundred and seventy-four subscribers and 1,332 junctions were connected to the new automatic equipment installed by the Automatic Telephone & Electric Company, Ltd., at 1.30 p.m. on May 17th. The equipment of standard line finder type has an initial capacity of 7,200, ultimate capacity 10,000. The batteries, plated capacity 1,200 Ah, box 1,650 Ah supplied by the Alton Battery Company, are charged by a divided battery float system with two motor generators of 300 and 100 A output.

STANDARD P.A.B.X. AT BROMLEY

A unit P.A.B.X. No. 1, equipped for 15 auto., 2 manual and 4 exchange lines, was installed at Bromley H.P.O. by Messrs. S. T. & C. Co. and brought into service on March 6th, 1939.

An attendant's cabinet is provided for answering incoming exchange calls, all other types of call being set up or transferred automatically under control of the extension user. Special features include provision for through clearing, direct access to exchange, "follow on" calls, calling back, auto. transfer, "camp-on" busy and night service to any extension. Three link circuits, using 2,000 type selector mechanism, are fitted, and the power arrangements comprise a mains operated automatic charging set feeding a 50 V floating battery.

THE ENGINEER-IN-CHIEF'S RADIO LABORATORIES, DOLLIS HILL

During the quarter, the lighting and power installation of the Engineer-in-Chief's Radio Laboratories at Dollis Hill was completed by the Power Section.

The work included the installation of 10 batteries and 2 batches of counter E.M.F. cells, together with their associated charging panels and rectifiers and the distribution of the A.C. and D.C. power to machines and benches located in the various laboratories.

The building comprises some 14 laboratories and 16 offices, including the drawing office, and there were more than 50 bench panels each to be fed with an A.C. and 2 D.C. supplies and 13 racks which are fed with an A.C. and 3 D.C. supplies. The capacity of the main A.C. board is 350 kVA.

Elaborate precautions were necessary to guard against any possibility of radio interference and A.C. cabling throughout the laboratories was carried out in lead-covered and steel-armoured cable and fitted with suppressor units. The D.C. cables were lead covered throughout.

Connections between the batteries and charging panels were made in lead-covered cable in galvanised iron conduit. A large proportion of the cabling work was carried out in floor chases and in all these chases a copper earthing strip was provided. This strip was connected to 18 earthing spikes buried under each of the two masts which flank the building.

The drawing and general offices have been provided with an under-floor duct system which is used for telephone as well as power cables.

WATER DAMAGE AT RELIANCE SUB-TANDEM EXCHANGE

At 10.30 p.m. on March 11th, during a heavy downpour of rain, water entered the apparatus room through the ceiling (due to building operations in progress) and dripped on to a large cable runway containing several hundred cables, mostly incoming and outgoing junctions situated over the first tandem selector houses. Prompt steps were taken to divert the water from the apparatus, and only six 33-wire cables carrying outlets from levels 2 and 3 to second tandem selectors were seriously affected. Within a very short time the shelf fuses on the affected second tandem selector board failed to hold and 36 circuits became unworkable and 24 others were partially affected. It was necessary to remove all the incoming junctions from the particular first tandem rack to other racks, where spare selectors already wired up pending the opening of Victoria, Rodney and Woolwich automatic exchanges were available.

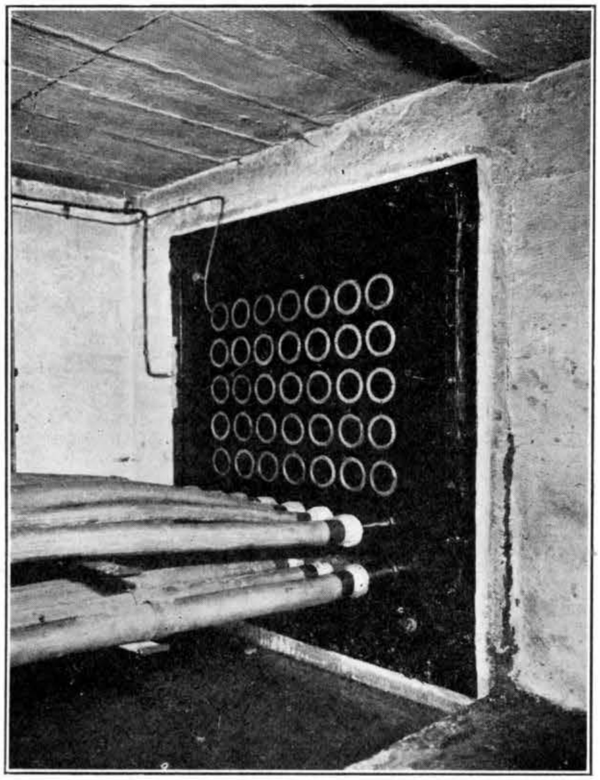
Seven electric fires, and seven vacuum cleaners used as blowers, one high pressure blower, and three cable heaters were employed to circulate warm air round the affected cables; by the afternoon of the 13th a considerable improvement was noted, many circuits being put back into service. The heating was continued until March 28th and a steady improvement in the insulation took place during this period, although it was noted that the A wires recovered their insulating properties at a much more rapid rate than the B wires which, of course, had the coloured insulation, and to which negative potential was normally connected. Meanwhile steps were being taken to renew the cabling, and on recovery of the old cables it appeared that in several cases slight arcing and burning had taken place between the individual conductors of some circuits, thus preventing any considerable improvement in the insulation; it might therefore have been advantageous to have removed the battery supply from all circuits connected to the affected cabling before the insulation dropped to its lowest value.

NOTTINGHAM OVERHEAD TRUNK ROUTE

The recovery of the Nottingham trunk route along the Hemel Hempstead Road from "The Dog" T.P. to Hunton Bridge is at present being effected. The route carried about 70 150 lb. copper wires, and was erected in 1908. In recent years it has followed the general tendency and has gradually become spare. It is, however, still in a good mechanical condition, and suffered very little damage in the snowstorm of January last. This is perhaps a tribute to the sound methods of construction employed, and in an age which dictates the disappearance of this phase of engineering practice it is with a shadow of regret that we acknowledge the passing of one of the last of the heavy routes in the Region.

DUCT SEAL AT MACAULAY

The uncompleted duct seal at Macaulay telephone exchange recently underwent an unforeseen "load-test." On April 25th, in the early evening, a 36-inch water main burst at the junction of Wandsworth Road and Stewarts Road, at a point approximately 200 yds. from Macaulay exchange. The tarmac road surface was forced open by the water and the Department's plant in the immediate vicinity suffered slight damage. The water then entered the duct route which here abouts runs downhill into the exchange manhole at Macaulay. Here the duct seal was only partly plumbed and did not impede the flow greatly; in the cable chamber, however, all the plumbing had been finished and this seal was thus subjected to a head of about 10 ft. of water,



corresponding to a pressure of 52 lbs. per square inch, which it withstood successfully for a period of at least ten hours until the Department's motor pumps succeeded in reducing appreciably the level of water in the exchange manhole.

As can be seen from the photograph, the water eventually forced a way through the cement grouting of the brickwork to the right-hand side of the seal and a small trickle of water emerged from this crack ; a bulge of about three-quarters of an inch developed in the centre of the seal.

North Eastern Region

ARMOURED CABLE LAYING ACROSS MOORLAND

At the beginning of the year a request was received for the provision of telephone circuits to a position on open moorland some 980 ft. above sea level. It was essential that the circuits were provided with the least possible delay and, after survey, it was decided to lay an armoured cable (15/20PCQL) to the exchange some 5½ miles distant. The shortest route, involving two miles of open moorland and 3½ miles of country lane, was chosen.

The use of mechanical aids such as the moledrainer and plough were precluded by unfavourable conditions on the route and the cable was laid in open trench. Casual labourers were recruited for excavating and cable laying, the work being supervised by Works Supervisors under the control of an Inspector detailed for the work.

Cable laying in the grass verge of the country lane was a comparatively simple matter. With the exception of a few sections where obstructions called for special consideration, the cable was laid in the trench direct from drums mounted on a Departmental lorry which proceeded slowly along the lane as the cable was paid off.

The laying of the cable across the moor presented difficulties. On account of the swampy and undulating nature of the ground, transport was not practicable—several farmers refused to undertake the task. It was, therefore, necessary to uncoil the cable and have it carried manually to the site of operations. The cable drums were set up on the edge of the moor and the cable paid off, each man accepting a length of 12 yds ; a post set up 12 yds. from the drum provided a simple and quick means of ensuring that equal spacing was obtained. The photograph below illustrates the "chain gang," as it was called, in action.

Certain portions of the moor were waterlogged and in places turned to running water due to excessive rains, and, to prevent any possibility of the cable rising to the surface, it was passed through steel pipe which was securely anchored. Steel pipe was also used to effect a crossing in the bed of a stream.

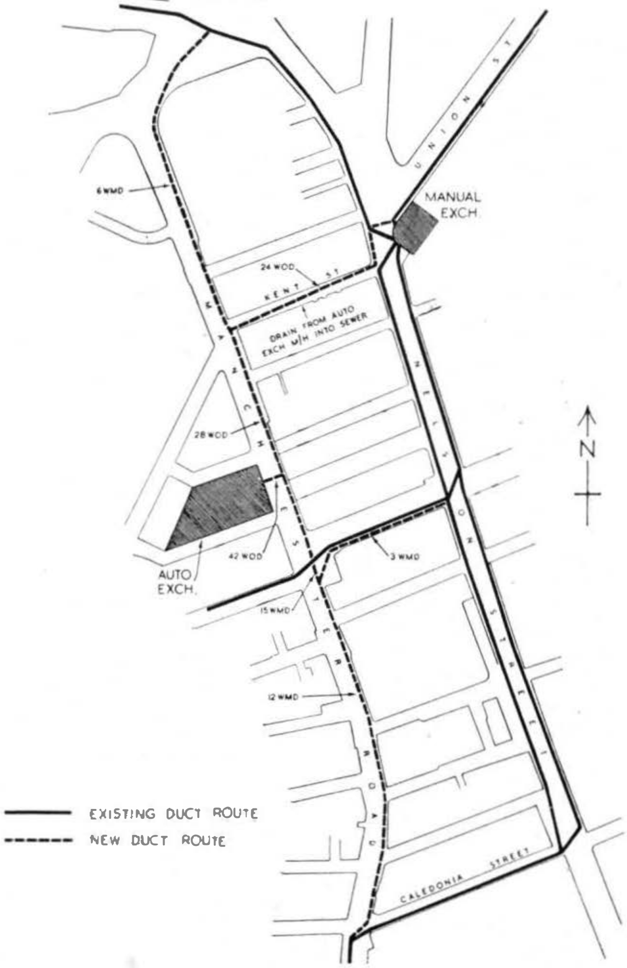
The subsoil of the moor was exceedingly stoney in sections and it became apparent during excavation that difficulty would be experienced in obtaining sufficient soft cover for the cable. The opportunity was, therefore, taken to place the heather crust on one side of the trench and the subsoil on the other side. Later, during reinstatement, the heather was replaced first, and formed an effective protection for the cable.

It was necessary to construct a loading coil manhole approximately half-way across the moor and a novel method of overcoming the conveyance difficulty was adopted. Approximately two-thirds of the sand and gravel was tipped at the lane end of the moor and the remainder was carted by a roundabout route to the terminal end. The labourers were provided with small bags and during certain trenching stages each man filled a bag and carried it to the site of the manhole, where it was emptied in passing. At the conclusion of the work session the empty bags were brought back and refilled preparatory for the next journey. In this manner conveyance costs were practically nil, the journeys having to be made in any case. The manhole frame and cover were carried on a pole improvised from a tree trunk.

By these methods the cable laying was carried out very expeditiously under very adverse conditions. Snow, sleet, rain and wind were almost continuous during the work and the cold was so intense that the labourers frequently worked in their overcoats. The severity of the conditions can be gauged by the fact that of the three night watchmen engaged the first gave notice after one night and the second after a week, and that substantial stays had to be provided to retain tents in position.

BRADFORD NEW AUTO. EXCHANGE

Duct Work. The plan shows the major portion of the underground conduit work, the commencement of which marked the beginning of the Bradford automatic area transfer scheme.



Enquiries of the Local Authorities indicated the presence of numerous mains in the vicinity of Bradford main exchange, and, after careful consideration, a decision was reached to cross the road with a 42-way octagonal duct, and to build a triangular-shaped manhole on the opposite side of Manchester Road. The disposition of the mains in the roadway was such that it would only be possible to cross at a depth below the main sewer running along Manchester Road, and measurements of its depth were taken north and south of the site.

As there had been some doubt as to the precise level of entry into the cable chamber, it gave immense satisfaction to find during tunnelling operations that the roof level just coincided with the line of flags upon which the sewer had been laid. The finished tunnel is illustrated in Fig. **1**.

Since Manchester Road rises for approximately two miles south of the Bradford main exchange, drainage for the exchange manhole had to be considered. This was made more difficult with the location of the new duct route being below the main sewer, but by running a drain pipe along Manchester Road and Kent Street underneath the new octagonal duct route an entry was obtained into a sewer in Kent Street. Fig. **2** shows the trench crossing Kent Street at a point near the entry of the drain into the sewer.

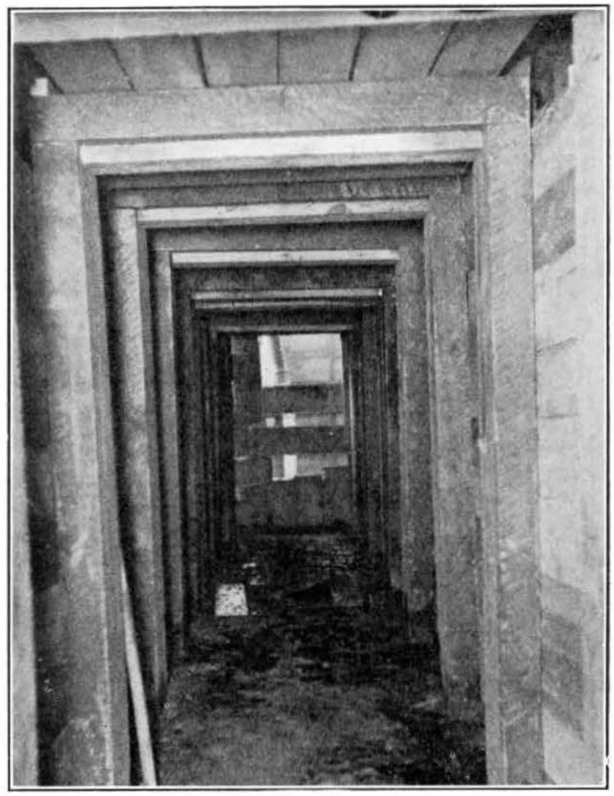


FIG. **1**

The linking up of the local network to the five satellite exchanges has also been completed.

FIG. **2**

CONVERSION OF WORKSOP MAGNETO EXCHANGE TO AUTOMATIC WORKING

This exchange was converted to automatic working on January 28th, 1939. It is of the non-director, line finder type, without manual board. Initial equipment of 700 lines is provided. The parent exchange is Sheffield.

An outstanding feature of the equipment is the M.D.F., which is an entirely new type. The frame is experimental and this exchange was chosen for the field trial, the installation being carried out by Messrs Siemens Brothers.

The main departures from the standard type are :—

(*a*) The provision of a complete plug-in type protector unit for each circuit, fitted on the line side verticals.

(*b*) The provision of test jacks, fitted vertically in strips of 20, on the numerical side, to which the exchange cabling is connected.

(*c*) The capacity per vertical is 300 on the line side and 200 on the exchange side, giving more accommodation for the external cable pairs which are always considerably in excess of the exchange equipment provided.

(*d*) A modified cable trench is provided. The trench is completely undercut to just beyond the protector mounting vertical to allow the external cables to have a " straight up " run, thus enabling a direct lead-off from the cable form to the protector termination via a 5-in. " skinner." The exchange cables are fed down the centre of the frame with a separate 20 pair distribution along the horizontal bars to each test jack strip. The external and exchange cable runs are, therefore, somewhat the reverse of what is effected on previous frames.

The protector is housed in a moulded bakelite fitting and embodies two new-type line fuses enclosed separately in one side of the unit. In the other side are fitted two delay action fuses—having similar operating characteristics to heat coils BB which they replace—and one double spark gap of the totally enclosed brass electrode type of arrester. When the unit is not *in situ* the line is completely disconnected. The arrester is connected to earth via a special contact.

The test jacks on the exchange side are of small type and a much improved type of test-slipper, with guide pins, is provided. Separate plugs are provided for N.U. connecting and P.B.X. busying. A special type of disconnecting plug, used solely for transfer purposes, is also available. This plug has a vertical hole in each side for the insertion of tapes in connection with the withdrawal of the plugs at the actual cut-over.

North Wales District

U.A.X. CONVERSION PROGRAMME

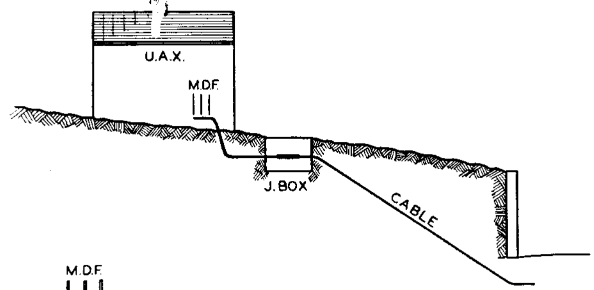
Oakamoor. The Oakamoor area was converted from manual (C.B.S.2) to U.A.X.13 working at 1.30 p.m. on Thursday, April 20th, 1939.

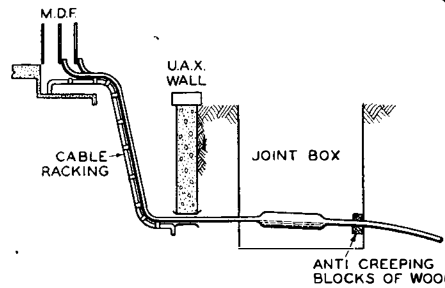
Four B/W junctions carry the traffic to the parent exchange at Stoke-on-Trent, 12 miles away, and three B/W junctions to Cheadle connect with the adjacent exchange areas.

The equipment comprises the following units :— 2 13A ; 3 13B ; and 1 13C. There are 53 ordinary subs. and 2 C.C.Bs.

The new U.A.X. is situated in the picturesque village of Farley, within a mile of the well-known beauty spot of Alton Towers. The opening of the U.A.X. was an innovation in more ways than one as the building was the first to be erected in this village for over 200 years. In order to blend with the surroundings, the building is of dressed Hollington stone. The use of this material resulted in a cost of £520.

The U.A.X. building stands in a field some 8 ft. above the road level. The lead-in had, therefore, to be somewhat unusual. It was not possible to make a joint near the M.D.F. and so the E.S. and W. terminating cable was taken over cable racking to a jointing chamber





outside the U.A.X. at a lower level of 4 ft. Here the cable had to be stoppered with wood blocks, in a similar manner to anti-creeping devices, as the drop in level from this point to the road is 5 ft.

Aston.—On Thursday, May 4th, 1939, the Aston Area (Crewe) was converted from C.B.S.2 to U.A.X.13 working.

There are 5 B/W junctions to the parent exchange at Crewe and 2 B/W junctions to Whitchurch. These junctions, together with 92 subscribers' circuits, were successfully transferred at 1.30 p.m.

The equipment includes 3 13A ; 2 13B ; and 1 13C units.

South Western District

AERIAL CABLING AT WITHERIDGE, DEVON

Some interesting aerial cabling experiments have been carried out recently at Witheridge in co-operation with the Engineer-in-Chief's officers. Several methods of erecting aerial cable were observed and the various operations involved in each method were timed, comparable sections of route being used in order to obtain a fair comparison of the different methods. A useful comparison was obtained of the method of erecting the cable direct from a vehicle using a bosun's chair with the method whereby the cable is drawn in through the cable rings, the latter (enclosing the pulling-in rope) having previously been placed in position by a workman operating from a chair. Other methods tried were that whereby the whole of the operations are carried out from the ladder derrick erected on a 30-cwt. vehicle and that of ringing and roping the steel strand on the ground prior to tensioning, the cable being drawn in subsequently through the rings. The relative advantages of the different methods were thus compared and the experience gained will no doubt assist the Engineer-in-Chief's officers in their consideration of standard methods of construction. Other interesting experiments with a chain type hauler and dynamometer were also carried out.

Staff Changes

Promotions.

From Deputy E.-in-C. to E.-in-C.

Name	District	Date
Angwin, Col. A. S.	E.-in-C.O.	1.6.39

From Asst. E.-in-C. to Deputy E.-in-C.

Name	District	Date
Ridd, P. J.	E.-in-C.O.	1.6.39

From S.E. to Asst. E.-in-C.

Name	District	Date
O'dell, G. F.	E.-in-C.O.	1.6.39

From C.R.E. to Deputy Reg. Dir.

Name	District	Date
de Wardt, R. G.	L.T. Reg.	1.4.39

From Reg. Engr. to T.M.

Name	District	Date
Morgan, C. E.	N.E. Reg.	1.5.39

From Exec. Engr. to T.M.

Name	District	Date
Cox, H. E.	L.T. Reg. to S.Wa.	13.3.39
Richardson, T.	Scot. Reg.	1.3.39

From Exec. Engr. to Reg. Engr.

Name	District	Date
Crompton, W. W. B.	N.E. Reg.	11.5.39

From Exec. Engr. to A.S.E.

Name	District	Date
West, W.	E.-in-C.O.	7.3.39
Morrish, H. E.	L.T. Reg. to E.-in-C.O.	10.5.39
Evans, G. T.	E.-in-C.O.	1.6.39
Stratton, J.	E.-in-C.O.	19.4.39

From Area Engr. to Area Engr. with Allowance

Name	District	Date
Brent, W. H.	N.W. Reg. to Scot. Reg.	30.5.39

From Asst. Engr. to Exec. Engr.

Name	District	Date
Lucas, F. N.	Sc. Reg. to E.-in-C.O.	1.4.39
Hadfield, B. M.	E.-in-C.O.	7.3.39
Gray, W. D.	L.T. Reg. to E.-in-C.O.	7.4.39
Evans, G.	E.-in-C.O.	10.3.39
Wood, G. E.	L.T. Reg.	1.6.39
Spears, G.	Scot. Reg. to L.T. Reg.	19.3.39
Greening, F. C. G.	L.T. Reg.	10.5.39
Ward, W. C.	N. W. to N. Mid.	26.3.39
Porter, J. E.	S. Mid. to N. Mid.	26.3.39
Hall, L. L.	E.-in-C.O.	10.3.39
Beastall, J. G.	E.-in-C.O. to N.W. Reg.	1.4.39
Vause, A. H.	L.T. Reg.	13.4.39
Summers, F.	S.Wa. to E.-in-C.O.	25.4.39
Speight, E. A.	E.-in-C.O.	13.4.39
Hayes, H. C. S.	E.-in-C.O.	21.4.39
Gill, F. W.	S.Wa. to E.-in-C.O.	23.5.39

From Chief Insp. to Asst. Engr.

Name	District	Date
Wain, S. W.	Rugby R/S to Portishead R/S	2.3.39
O'Roark, A. F.	N.Wa. to S.W.	26.3.39
Smith, J.	N.E. Reg. to E.-in-C.O.	29.3.39
Read, H.	S. Midland	4.4.39
Greenbury, L. J.	N.E. Reg. to Sc. Reg.	16.4.39
Smith, C. N.	Sc. Reg. to L.T. Reg.	7.5.39
Barry, C.	N. Ire. to S.Wa.	25.4.39
Wooding, W. T.	L.T. Reg.	13.4.39

From C.I. to C.I. with Allowance

Name	District	Date
Beaumont, H. R.	N.E. Reg.	19.2.39
Partington, H. J.	N.W. Reg.	1.4.39

From Insp. to Chief Insp.

Name	District	Date
Henk, A. J. C.	E.-in-C.O. to N.E. Reg.	19.3.39
Cope, H. G.	E.-in-C.O. to N.E. Reg.	1.4.39
Smith, G. J.	E.-in-C.O. to N.W. Reg.	1.4.39
Gerry, P. R. C.	E.-in-C.O.	30.10.38
Seymour, R. A.	E.-in-C.O.	23.12.38
Cunningham, J. F.	S.Lcs. to N.W. Reg.	1.4.39
Wilcher, F. B.	E.-in-C.O.	2.12.38
Day, J. V.	N.E. Reg. to N.W. Reg.	1.4.39
Sutton, C. J.	S. Wales	19.5.37
Field, A. H. G.	S. Wales	21.3.38
Betts, E. H.	L.T. Reg. to S.Wa.	26.3.39
White, A. H.	L.T. Reg. to N.E. Reg.	1.4.39
Fisher, S. W.	L.T. Reg.	26.2.39
Marchant, P. A.	E.-in-C.O.	10.10.38
Myers, B. L.	E.-in-C.O. to N.W. Reg.	16.4.39
Wright, F. E.	E.-in-C.O. to N.E. Reg.	29.3.39
Evans, W. A. A.	L.T. Reg.	6.3.39
Wash, H.	E. to S. E.	13.4.39
Watling, C. E. C.	L.T. Reg.	3.5.39
Boon, J. W. H.	E.-in-C.O. to N.W. Reg.	1.4.39
Blaney, H. J.	N. Ireland	20.4.39
Hall, A. W.	E.-in-C.O. to N.W. Reg.	7.5.39
Thorn, F. W. J.	E.-in-C.O.	3.5.39
Shaddick, W. G.	E.-in-C.O.	16.4.39

From Draughtsman Cl. I to Chief Insp.

Name	District	Date
Deacon, T. A. F.	E.-in-C.O.	30.4.39

From Area M.T.O. to Reg. M.T.O.

Name	District	Date
Withers, C. A.	N.W. Reg.	1.4.39

From Tech. Asst. to M.T.O. III

Name	District	Date
Dunn, C.	Exeter to E.-in-C.O.	1.4.39

From Mech.-in-Charge to T.A.

Name	District	Date
Swire, W. L.	Reading to Ldn.	27.3.39
Leech-Brown, D. C.	B'ham. to Exeter	1.4.39

From Asst. Chem. to Chem.

Name	District	Date
Edwards, W. T.	T.S. B'ham.	To be fixed later
Bowcott, H. J.	T.S. B'ham. to T.S. Ldn.	To be fixed later

From S.W.1 to Insp.

Name	District	Date
Dovey, J. F.	T.S. B'ham.	26.3.39
Hawes, A. E.	S. Wales	23.9.38
Foote, S. B.	S. Wales	23.9.38
Anderson, L.	S. Wales	23.9.38
Lewis, E. J.	S. Wales	24.3.39
Denton, E. H.	N.W. Reg.	26.3.39
Walton, F.	N.W. Reg.	4.9.38
Goodwin, H.	N.W. Reg.	19.2.39
Gore, F.	N.W. Reg.	26.3.39
Jefferson, J. C. C.	N.W. Reg.	31.7.38
Barlow, O. N.	N.W. Reg.	28.5.38
Parker, H.	N.W. Reg.	3.4.38
Kilgour, A. A.	N.W. Reg.	19.10.38
Cole, R. A.	S. Eastern	29.3.39
Hewson, E.	N.W. Reg.	23.9.38
Helliwell, W. H.	N.W. Reg.	28.5.38
Lunt, J. J.	N.W. Reg.	23.9.38
Sharples, W.	N.W. Reg.	11.3.39
Kirkham, J.	N.W. Reg.	1.2.39
Leyland, A.	N.W. Reg.	23.9.38
Sketcher, J. H.	N.W. Reg.	To be fixed later
Howard, J. H.	N.W. Reg.	To be fixed later

Promotions.—*Continued*

Name	District	Date
From S.W.1 to Insp.—Continued.		
Hughes, J. W.	N.W. Reg.	23.9.38
Wright, J. E.	E.-in-C.O.	25.11.38
Cranston, W. D.	E.-in-C.O.	20.11.38
Coopersmith, M.	E.-in-C.O.	27.11.38
Fitch, J. W.	E.-in-C.O.	13.11.38
Roper, L. W.	E.-in-C.O.	13.11.38
Glass, V. G.	E.-in-C.O.	30.11.38
Gallagher, F.	Oxford R/S	15.11.38
Collingbourne, H. L.	S. Western	10.3.39
Bradley, S. V.	N. Wales	To be fixed later
Pritchard, H.	N. Wales	To be fixed later
Proctor, F. A.	N. Wales	To be fixed later
Marmot, A. D.	N. Wales	To be fixed later
Morley, G.	L.T. Reg.	9.2.39
Pilgrim, W. R. O.	L.T. Reg.	4.3.39
Macken, W. E.	L.T. Reg.	12.2.39
Chapman, E. W.	L.T. Reg.	4.3.39
Cheyney, C. E.	L.T. Reg.	6.3.39
MacKay, E. D.	N. Ireland	20.4.39

Transfers.

Name	District	Date
C.R.E.		
Morris, A.	S.Lcs. to L.T. Reg.	1.4.39
Carter, H.	S.Wa. to Scot. Reg.	1.5.39
Exec. Engr.		
Heil, H.	E.-in-C.O. to Foreign Office	1.4.39
Asst. Engr.		
Brown, H. R.	N.W. to E.-in-C.O.	2.3.39
Wilson, F.	Portishead R/S to E.-in-C.O.	26.2.39
Asst. Engr.		
Kilburn, G. A. N.	S.Lcs. to L.P.R.	1.4.39
Atkinson, J.	E.-in-C.O. to N.W. Reg.	14.5.39
Chief Insp.		
Woodhead, H. C.	Leafield R/S to Rugby R/S	5.3.39
M.T.O. III		
Whitehurst, J. F.	E.-in-C.O. to N.W. Reg.	1.4.39

Retirements.

Name	District	Date
Engr.-in-Chief		
Lee, Sir George	—	31.5.39
A.S.E.		
Maddock, G. M.	E.-in-C.O.	31.3.39
Vickery, W.	E.-in-C.O.	9.5.39
Exec. Engr.		
Banks, A. E.	N. Midland	5.2.39
Chief Insp.		
Quinn, F.	S. Midland	30.4.39
Hilton, W. B.	S. Lancs	31.3.39
Coxon, F. A.	N. Wales	3.4.39
Kilgour, R.	Sc. Reg.	31.5.39
Technical Asst.		
Grover, E.	London	17.3.39
Insp.		
Sanderson, A.	N.E. Reg.	31.3.39
Dunnett, D. C.	S. Lancs.	31.3.39
Anderson, J. T.	N.E. Reg.	31.1.39
Little, J. W.	N.E. Reg.	20.3.39
Holden, F.	N. Wales	10.4.39
Comins, T.	S. Western	31.3.39
Thwaites, C. H.	L.T. Reg.	25.4.39
Weinel, C. F. G.	L.T. Reg.	31.3.39
Taylor, W.	Eastern	25.4.39
Sait, G.	S. Midland	31.3.39
Hutton, R.	Scot. Reg.	22.4.39
Sadler, A. T.	L.T. Reg.	26.4.39
Little, J. W.	N.E. Reg.	20.3.39
Sim, J. S.	Scot. Reg.	3.6.39
Henry, J.	S. Midland	31.5.39
Hulse, J. H.	N.W. Reg.	14.5.39
Hammett, G. G.	L.T. Reg.	27.5.39

Secondments.

Name	District	Date
Asst. Engr.		
Blackstaff, H. P.	E.-in.C.O. to War Office	13.2.39
Chief Insp.		
Thwaites, H. J.	E.-in-C.O. to Air Ministry	30.3.39

Appointments.

Name	District	Date
Probationary Insp. (Ltd. Comp., Sept., 1938)		
Morton, J. Y.	Trg. Sch.	1.3.39
Preece, G. H.	Trg. Sch.	1.3.39
Pengelly, I. E.	Trg. Sch.	1.3.39
Hudson, G. K.	Trg. Sch.	1.3.39
Broadhurst, F.	Trg. Sch.	1.3.39
Parsons, R. J.	Trg. Sch.	8.5.39
Bird, G. A.	Trg. Sch.	1.3.39
Sard, G. J.	Trg. Sch.	1.3.39
Harris, K. E.	Trg. Sch.	1.3.39
Liddiard, F. E.	Trg. Sch.	1.3.39
Groves, H.	Trg. Sch.	1.3.39
Easton, K. J.	Trg. Sch.	1.3.39
Dodd, G. A.	Trg. Sch.	1.3.39
Davis, R. E.	Trg. Sch.	1.3.39
North, G. W.	Trg. Sch.	1.3.39
Richards, R. M.	Trg. Sch.	1.3.39
Bennett, D. G.	Trg. Sch.	1.3.39
Tarry, K. W. D.	Trg. Sch.	1.3.39
Knight, E. D.	Trg. Sch.	2.3.39
Atkinson, F.	Trg. Sch.	1.3.39
Fell, H. J. P.	Trg. Sch.	1.3.39
Kynaston, W. I.	Trg. Sch.	1.3.39
Farnworth, A.	Trg. Sch.	1.3.39
Iles, A. R.	Trg. Sch.	1.3.39
MacDonald, J. A.	Trg. Sch.	1.3.39
Blair. G. M.	Trg. Sch.	1.3.39

Name	District	Date
Open Comp., Sept., 1938		
Keast, M. H.	Trg. Sch.	1.3.39
Bampton, J. F.	Trg. Sch.	1.3.39
Stotesbury, K. E.	Trg. Sch.	1.3.39
Marshall, F. K.	Trg. Sch.	1.3.39
Jones, E. W.	Trg. Sch.	1.3.39
Curtis, G. D.	Trg. Sch.	1.3.39
Staunton, H. P.	Trg. Sch.	1.3.39
Bassett, H. G.	Trg. Sch.	1.3.39
Sumner, G. C.	Trg. Sch.	1.3.39
Attree, V. H.	Trg. Sch.	1.3.39
Ash, W. S.	Trg. Sch.	1.3.39
Durant, R. F.	Trg. Sch.	1.3.39
Hamer, R.	Trg. Sch.	1.3.39
Bennett, T. J.	Trg. Sch.	1.3·39
Pritchard, G. F.	Trg. Sch.	1.3.39
Gibbons, A. G.	Trg. Sch.	1.3.39
Stanier, J. H.	Trg. Sch.	1.3.39
Pickard, R. J.	Trg. Sch.	1.3.39
Smith, D. C.	Trg. Sch.	1.3.39
Elkins, N. A.	Trg. Sch.	1.3.39
Marsh, S. T.	Trg. Sch.	1.3.39
Hughes, L. S.	Trg. Sch.	1.3.39
Morris, K. W.	Trg. Sch.	1.3.39
Thompson, R. H.	Trg. Sch.	1.3.39
Shore, A.	Trg. Sch.	1.3.39
Arnett, J. A.	Trg. Sch.	1.3.39
Message, R. O.	Trg. Sch.	1.3.39
Taylor, R. E.	Trg. Sch.	1.3.39
Webb, P. B.	Trg. Sch.	1.3.39

Deaths.

Name	District	Date
Chief Insp. with Allowance		
Meiklejohn, G. F.	Scot. Reg.	2.5.39

Name	District	Date
Chief Insp.		
Burnell, C. J.	L.T. Reg.	18.2.39
Wood, W. J.	S. Eastern	8.3.39

Communications

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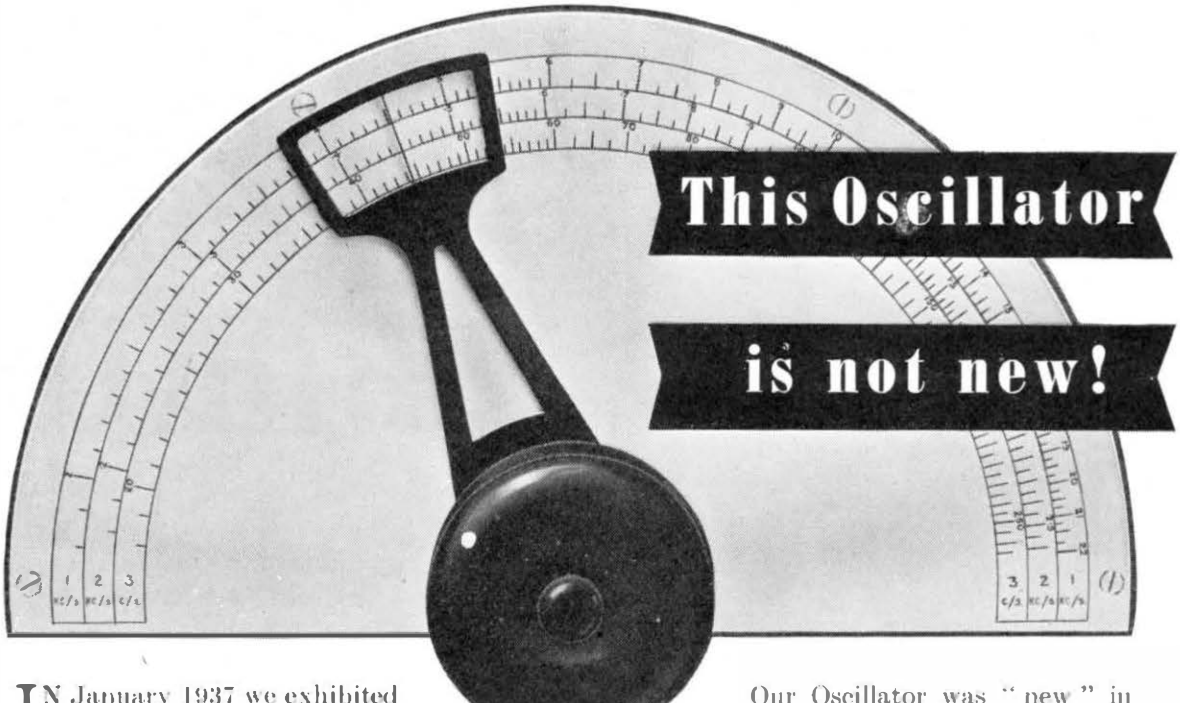

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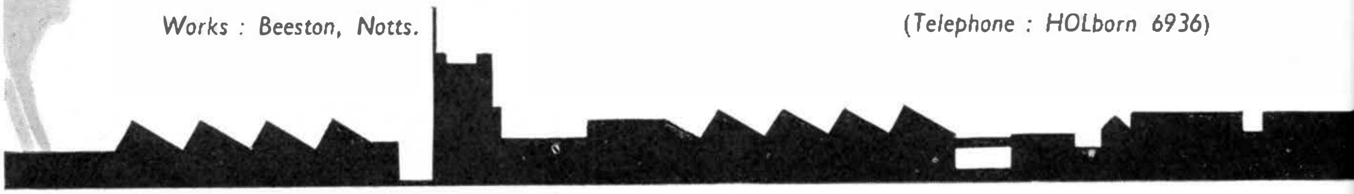


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