THE POST OFFICE ELECTRICAL ENGINEERS' JOURNAL

VOL. 32 APRIL, 1939 PART 1

CONTENTS

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0- 200 ,,	2 ,,
0- 400 ,,	4 ,,
0- 500 ,,	5 ,,
0-1,000 ,,	10 ,,

D.C.

Range.	Value per division
0- 50 mV (1 mA range)	0.5 mV
0- 100 mV (2 mA range)	1 ,,
0- 500 mV	5 ,,
0- 1 Volt	10 ,,
0- 5 ,,	50 ,,
0- 10 ,,	100 ,,
0- 50 ,,	500 ,,
0- 100 ,,	1 Volt
0- 200 ,,	2 ,,
0- 400 ,,	4 ,,
0- 500 ,,	5 ,,
0-1,000 ,,	10 ,,

CURRENT

A.C.

Range.	Value per division
0- 5 mA	50 μA
0- 10 ,,	100 ,,
0- 50 ,,	500 ,,
0-100 ,,	1 mA
0-500 ,,	5 ,,
0- 1 Amp.	10 ,,
0- 5 ,,	50 ,,
0- 10 ,,	100 ,,

D.C.

Range	Value per division
0- 1 mA	10 μA
0- 2 ,,	20 ,,
0- 5 ,,	50 ,,
0- 10 ,,	100 ,,
0- 50 ,,	500 ,,
0-100 ,,	1 mA
0-500 ,,	5 ,,
0- 1 Amp.	10 ,,
0- 5 ,,	50 ,,
0- 10 ,,	100 ,,

RESISTANCE

Range.	First indication.	
0-10,000 ohms	0.5 ohms	using internal 1½-volt cell.
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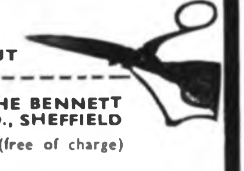

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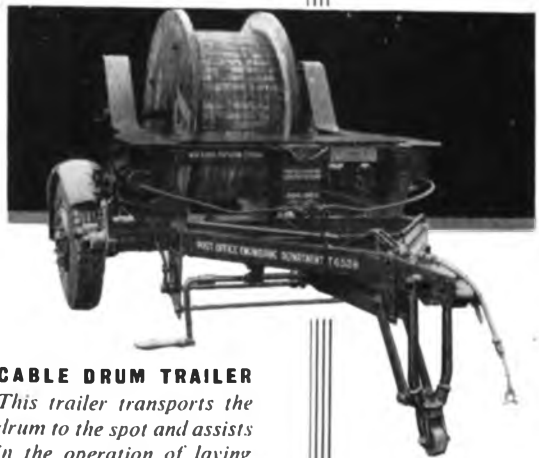

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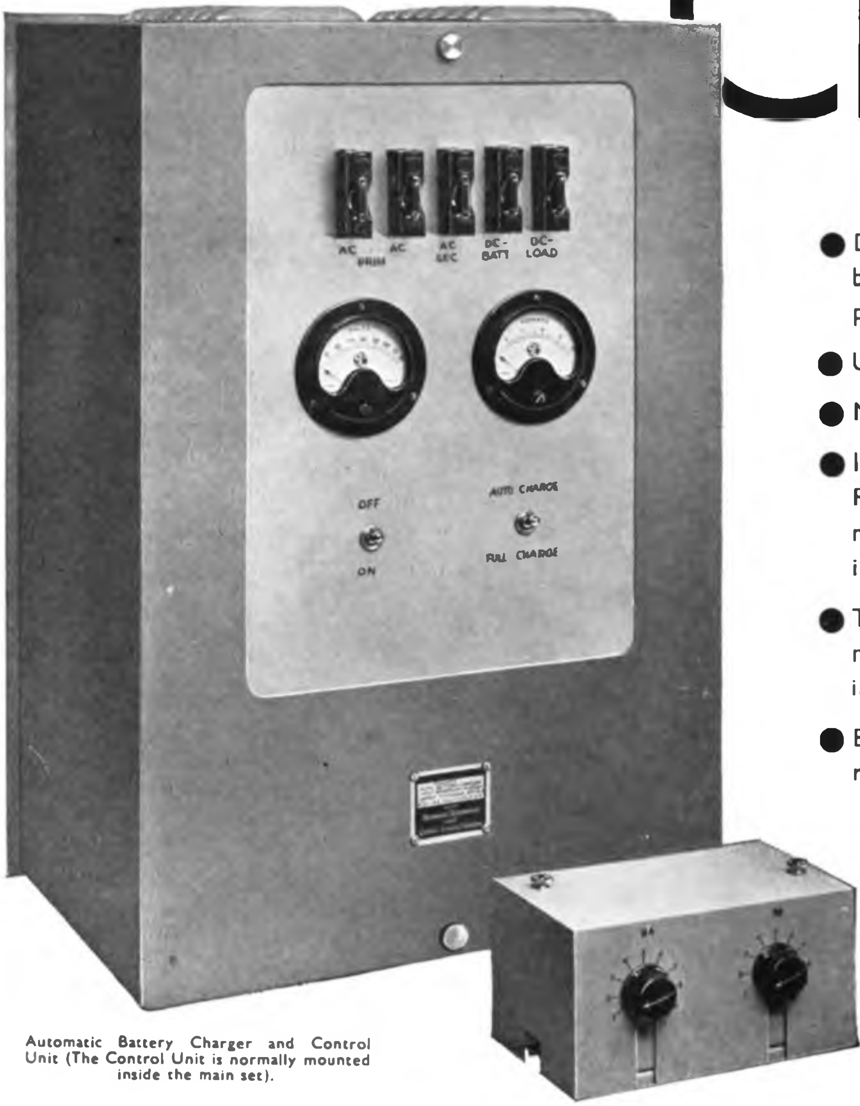

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The Post Office Electrical Engineers' Journal

Vol. XXXII April, 1939 Part I

A Mobile Automatic Telephone Exchange

R. W. PALMER, A.M.I.E.E., and G. A. O. ABBOTT

U.D.C. 621.395.3.4 621.395.722 629.113 621.355

The Post Office has built a standard Unit Automatic Exchange No. 12 for 100 lines in a vehicle which can be towed to rural sites for temporary service. This experimental mobile exchange is self-contained, and the authors describe the construction of the trailer, the transport and telephone facilities, and the alternative arrangements for charging the batteries from the petrol engine charging set or from a public A.C. supply.

Introduction.

An automatic telephone exchange suggests to the mind a permanent building housing an assembly of equipment and power plant for the purpose of controlling the switching of circuits within an area and thus providing a continuous telephone service for a period of years. The time taken for the provision of a small automatic exchange of the unit type may vary from six months, when suitable accommodation is available, to over a year, when difficulties in obtaining a site occur. The desirability of being able to provide an exchange at very short notice has led the Post Office to design and build experimentally a trailer vehicle completely equipped as a small unit automatic exchange for not more than 100 subscribers.

The need for the urgent provision of a rural or small urban exchange occurs more often than is generally realised, and some of the special circumstances for which a temporary unit is required to serve an area until permanent plant can be installed are : —

(*a*) Replacement of a small manual exchange following the sudden termination of the service of a caretaker-operator by death or other unforeseen circumstance.

(*b*) Replacement of a unit automatic exchange while it is being replaced by one of a larger size within the confines of the original permanent building.

(*c*) Replacement of a small automatic or manual exchange which has been damaged by fire or flood.

(*d*) Provision of a new exchange to meet unexpected development such as in connection with the defence services.

(*e*) Provision of exchange service to cover unavoidable delays in the scheduled erection or extension of a U.A.X. building or in the acquisition of a suitable site.

(*f*) Relief to a non-director automatic exchange.

It will be realised that the provision of an exchange may require the finding and negotiation of a site ; the renting or erection of a building ; the delivery of exchange equipment ; the cabling of the units ; the provision of the power plant ; and the final acceptance testing of the exchange as a whole.

Under emergency conditions, any scheme which would enable a telephone service to be provided in the shortest possible time is of advantage to the public as well as to the Post Office revenue and prestige. The provision of an exchange complete in every detail, and the reduction of the site problem to one of negotiation for vehicle parking space, materially reduce the time required to provide service and permit the normal procedure to be followed for the subsequent provision of the permanent exchange.

The modification of the subscribers' instruments and lines is work which would be necessary in any conversion from manual to automatic working and this work can be commenced before the mobile unit arrives.

General Design.

The first step towards the provision of a mobile exchange was taken in the Scottish Region where urgent service was provided successfully by installing a unit automatic exchange in a trailer caravan. The trailer was not built for carrying any great load and it was necessary to install the equipment after the vehicle had been positioned on site, but the success of the experiment was such as to justify the building of an exchange that would be fully mobile and completely self-contained. It was originally suggested that a mobile exchange unit should be designed with capacity for 25 subscribers and should be capable of being transported either by road or by rail. After protracted discussions, it was finally decided in April, 1938, that the provision of a single exchange of this type should be produced experimentally by the Circuit Laboratory of the Engineer-in-Chief's Office, no precise specification being given. In the first place, rail transport had to be ruled out because it was desired to use standard U.A.X. units which are 6 ft. 10 in. high, and would therefore involve difficulties in keeping within the limits of the railway loading gauge, and in transferring this heavy equipment to road transport, to complete the journey to some rural site.

Lack of time precluded any attempt to design a vehicle specially to accommodate exchange equipment, and it was decided to utilise the basic design of a 4-wheeled trailer vehicle used by the Defence Services.

This defined the principal dimensions, the floor area

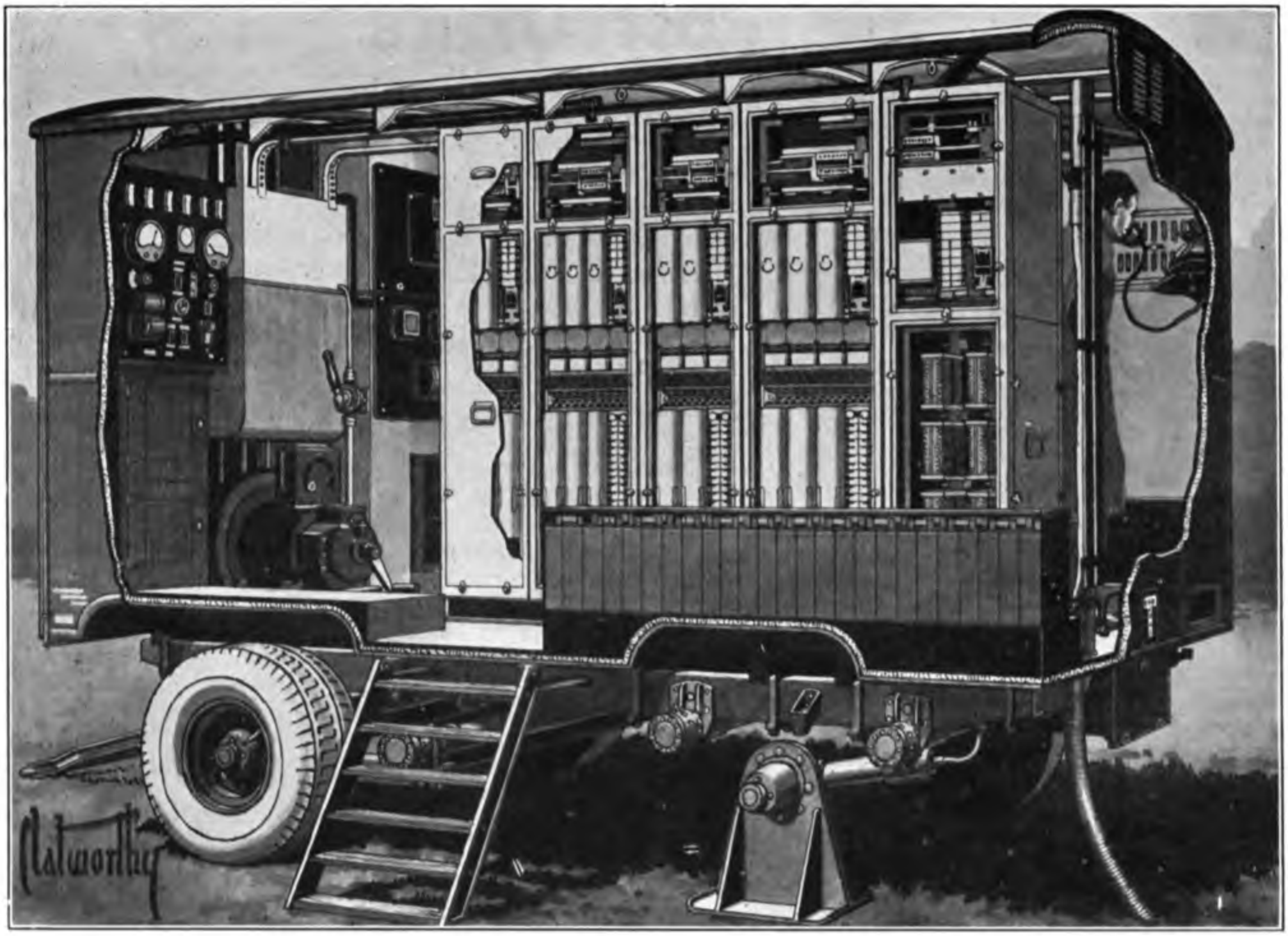

FIG. 1.—GENERAL VIEW OF THE VEHICLE AND EQUIPMENT.

being approximately equal to that of the equivalent standard U.A.X. No. 12 brick building, but it was necessary to rearrange the layout to provide balanced distribution of weight and low centre of gravity, and to meet other requirements of a road vehicle. A full-size model was constructed on the laboratory floor in canvas and timber in order to study the maximum amount of equipment which could be housed under these limitations. Some of the automatic exchange equipment was available for use in this model, and the remainder was simulated by rough shapes constructed mainly of cardboard. After many re-arrangements and practical tests for accessibility, it was found that the floor area of 15 ft. 9 in. × 7 ft. with a maximum height of 7 ft. was sufficient to house symmetrically a completely equipped U.A.X. No. 12 equipment for 90 subscribers and 10 junctions, together with duplicate batteries, duplicate charging plant (A.C. rectifier and petrol engine charging set), and all other standard facilities required in such an exchange. The final arrangement is shown in Figs. **1** and **2**. The necessary departures from standard equipment were limited to certain items of the power plant and were :—

(1) The adoption of traction type batteries (which are smaller) and the enclosing of these batteries in two lockers at floor level, so that they do not seriously impede access to the exchange units.

(2) The abandonment of full accessibility to the petrol engine from within the bodywork, access to one side being from the outside of the vehicle.

(3) The adoption of radiator cooling for the petrol engine in place of tank cooling.

At this stage, a provisional specification for the vehicle was prepared but some details of the bodywork had to be settled in co-operation with the contractor while erection was proceeding. After completion of the bodywork the empty vehicle was brought to the West Postal Yard in King Edward Building where the exchange equipment was installed, cabled, and

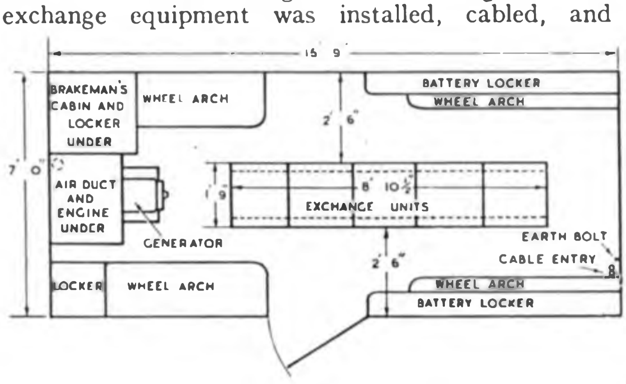

FIG. **2**.—FLOOR PLAN.

finally tested out. On completion the vehicle was inaugurated by the Postmaster-General at a ceremony described previously in this JOURNAL[1].

Chassis.

The 4-wheel torsion bar trailer chassis, Fig. **3**, was supplied by Messrs. J. Brockhouse & Co., Ltd., West Bromwich, and is the same as that commonly employed by the Royal Air Force for carrying special signalling equipment at speed over rough country. The independent springing consists of four torsion bars, one for each wheel. The bars are about 5 ft. long and 1⅞ in. in diameter, and are of silico manganese spring steel, oil-hardened and tempered, with an ultimate tensile strength of 85-100 tons per square inch. Each one is encased in a tube extending across the whole width of the chassis and one end is anchored to the chassis by a splined sleeve. The other end passes through a bearing and is then splined to a tubular crank arm, termed the "oscillating arm," at the extremity of which is a stub axle on which the wheel is mounted. The load on the wheel is therefore taken up by the twisting of the torsion bar and this provides a system of springing which is very smooth, completely adjustable and capable of following the contour of rough ground with a minimum of disturbance to the level of the body of the vehicle.

FIG. **3**.—TORSION BAR TRAILER CHASSIS.

The two front wheels are mounted on a turn-table with freedom to rotate 45° on either side of the straight-forward position, and the draw bar attached to this turn-table terminates at a steel coupling eye.

Ministry of Transport regulations limit the speed of a 4-wheel trailer to 20 m.p.h. and also demand that there shall be independent control of the trailer brakes when positive control by the driver of the towing unit is not provided. Over-run brake systems are not permitted on heavy trailers.

As it is not known what type of tractor will be hired on the occasions when the exchange is to be moved, it is essential to have facilities for independent control by a brakeman, for whom a cabin is provided on the trailer as seen in Fig. **4**. In addition to the brake lever in this cabin, there is a second brake lever located on the near side of one of the main chassis members for use as a parking brake when the trailer is being manœuvred into position by hand.

Each of these brakes will operate, independently, the Lockheed hydraulic brake system on the four wheels.

[1] *P.O.E.E.J.*, Vol. **31**, p. **285**.

As the weight of the complete vehicle, when loaded, is 5 tons 14 cwt. it is not possible to manœuvre it by hand except on concrete or similar level surfaces, and, even then, about twelve men are required for the purpose. When the mobile exchange has arrived at the temporary exchange site, it is desirable that the pneumatic tyred wheels should be removed to a place of safety, if only to avoid the damaging effects of the weather on the rubber, and the more usual system of jacking up the chassis has been abandoned in favour of the provision of heavy steel feet which can be bolted on to the axles in place of the wheels. These feet, or dummy wheels, can be seen in use in Fig. **1**, and are normally carried on the vehicle. This scheme of supporting the weight on the axles instead of on the main chassis members has the advantages that distortion of the chassis and body is reduced if the foundation is uneven, the material for supports is always to hand, and the operation can be carried out by one man.

Bodywork.

The body was supplied by Messrs. E. G. Brown & Co., Ltd., Tottenham, and, although the general construction is in agreement with the standard designs previously produced by that company the arrangement of the steel channel members forming the framework has been altered to suit the particular location of the telephone exchange equipment. All joints in this framework are welded in order to obtain the advantage of strength and freedom from bolts or rivets which might rust or become loose. A further protection against distortion is the addition of small webs of heavy sheet steel

FIG. **4**.—VIEW SHOWING BRAKEMAN'S CABIN.

welded into the angles at the top and bottom of each vertical member. (Fig. **1**). The floor framework is specially strengthened where securing bolts for equipment are required, and the floor itself consists, first of sheet steel laid on the frame members, then a 1 in. layer of insulating cork, then a second covering of sheet steel, and finally a covering of $\frac{3}{16}$ in. rubber, which is provided mainly as a protection against electric shock from the A.C. power supplies. The floor covering is turned up where it meets the side walls so that there are no sharp angles or corners to collect dust. To maintain a low centre of gravity, the floor is built as near as possible to the chassis members. This necessitates wheel arches rising 6 in. above floor level to provide wheel clearance. These wheel arches are, however, arranged with flat tops and are covered with rubber, in the same way as the rest of the flooring, in order that they can be used as an effective part of the available floor area.

The whole of the walls and roof are similarly constructed with 1 in. of cork insulation between the steel sheets but no rubber insulation was considered necessary. Special steps were taken to guard against rust, the screws securing the steel panels being tinned and treated with an additional rust-resisting preparation. The door is located on the near side in a position selected with reference to the problem of getting the exchange units into the vehicle. The door itself is also constructed of metal panels and cork insulation and the edges are specially designed to make a weather-proof joint when the door is shut. A Yale type standard U.A.X. lock is fitted and a letter box has also been incorporated for use when it is necessary to send official correspondence or instructions direct to the mobile exchange at the site which it may be occupying. For access at the doorway, a flight of steel steps is provided for bolting into position when the unit is on site. When travelling, the steps are housed in a simple fixing underneath the main chassis members.

The brakeman's cabin encroaches considerably on the space available inside the body, but, by careful arrangement of the accessories mounted in the forward end of the vehicle, and by using the space underneath the brakeman's seat for a tool locker, accessible from the inside, the loss of effective space has been reduced to an absolute minimum. The walls between the brakeman's seat and the interior of the vehicle contain cork insulation, but no such insulation is necessary in the other boundaries of the cabin. The cabin is accessible only from the outside, the door being opened and folded back flush with the forward wall of the body when the vehicle is travelling. On arrival at site, the cabin door is shut and locked with a standard U.A.X. lock and it was specially arranged that the brake lever in the cabin has to be in the " ON " position before the cabin door can be shut.

The window beside the brakeman is capable of being opened in order that hand signals can be given to following traffic, but the four windows in the main part of the vehicle are permanently shut in order to reduce the risk of dust entering the telephone exchange equipment. These windows are provided with sliding steel shutters on the inside so that they can be closed while the vehicle is unattended and will prevent damage to the equipment even if a window should be smashed accidentally or otherwise. This precaution is taken in addition to the provision of Triplex glass. Ventilation is provided by five ventilators, two on each side and one at the rear end, each being fitted with a gauze filter and an adjustable shutter to control the aperture. The outside face of each ventilator is covered by louvred panelling to exclude rain.

A locker, with access only from the outside, is built underneath the floor at the rear end to accommodate the four steel feet and other heavy tackle associated with the transport aspect of the vehicle. Two interior lockers, one of which is provided with drawers to accommodate small tools, are built into the forward end of the bodywork, Fig. **5**, one underneath the brakeman's seat, and the other in the opposite corner, where it forms a support for some of the power switchgear. The most important of the lockers are those for housing the batteries, the weight of which is such that a symmetrical arrangement is essential. The two batteries, weighing approximately $\frac{1}{4}$ ton each, are, therefore, housed separately, one above each of the rear wheel arches, Figs. **1** and **6**. This also keeps the centre of gravity as low as possible. The steelwork in these lockers has been specially treated with anti-corrosive paint, and the cells themselves stand on wood blocks. The lockers enclose the batteries completely and are provided with their own small ventilators, giving direct access to the outside air. Since none of the lockers can form a table as normally provided in a unit automatic exchange, and also as space is not available for a fixed table, a folding table and seat are provided under one of the windows where they obstruct the gangway only when in actual use. Figs. **5** and **6** are photographs taken before the exchange units were installed, but the two girders on which the units are to be mounted can be seen.

Provision had to be made for the following cable entries through the floor or walls of the bodywork.

(1) Entry through the floor at the forward end for an underground electric supply cable, and for an earth wire for connection to the supply company's switch gear.

(2) Entry through the top of the forward end wall for an overhead electric supply cable.

(3) Entry through the floor at the rear end for an earth wire for connection to the bodywork and telephone equipment, independently of the power supply earth.

(4) Entry through the floor at the rear end for an underground telephone cable.

The telephone cable required special consideration, and it has been arranged for the cable to be protected between the ground and the underside of the vehicle by a 2 in. diameter flexible metal tube which can be attached by a screwed coupling.

The complete vehicle is painted the standard Post Office green on the outside, with the addition of the G.P.O. monogram and the inscription " Mobile Automatic Telephone Exchange " on the two sides

FIG. 5.—INTERIOR VIEW—FRONT END.

FIG. 6.—INTERIOR VIEW—REAR END.

and on the rear panel. Up to shoulder level the interior is painted a light grey to match the telephone exchange units and to give as much reflected light as possible. Lockers and metal fittings are painted green, and the roof, together with the upper part of the walls, is painted white in order to help in obtaining adequate natural light under conditions of plant congestion.

Six bulkhead lighting fittings of an attractive type, supplied by Messrs. Holophane, are spaced three on each side wall, the four corner fittings (60 watts each) being connected to the electric supply mains, and the two centre units (25 watts each) being connected to the exchange battery. Each of these lighting systems is provided with a time switch to guard against the lights being left on when the vehicle is unattended. Local switches in the circuits permit either set of lights to be operated at will, and all wiring is enclosed in steel conduit.

Power Supplies.

The duplicate secondary batteries each consist of twenty-five 72 ampere-hour cells of the traction type, manufactured by the D.P. Battery Co. The principal battery charging equipment from the point of view of accommodation in the vehicle is the petrol engine set, which is a standard unit as supplied to the Post Office by Messrs. Petters of Yeovil for all small unit automatic exchanges. It consists of a 2 h.p. water-cooled single cylinder petrol engine directly coupled to a 500 watt D.C. generator, and is mounted centrally on the floor at the forward end (Fig. 5) on rubber anti-vibration washers and a galvanised steel tray with drainage for surplus water or oil which otherwise might collect.

There is, however, an important difference from the standard U.A.X. equipment in that radiator cooling has been adopted in place of tank cooling in order to save space and weight. A pulley, fitted at the forward end of the petrol engine, is coupled by a whittle belt to the fan associated with the large radiator immediately above the engine. Access for inspection of this belt and of other parts of the engine on that side is facilitated by a door in the wall of the vehicle. Incidentally, this door is used as the means of entry for the engine during installation or replacement. The radiator fan draws air through louvres in the forward end of the vehicle, forces this air through the radiator and discharges the heated air through an enclosed duct. This air duct terminates at louvres high up in the end wall and prevents the hot air from circulating in the main body of the mobile exchange.

The engine runs unattended until the automatic trip comes into operation when the battery is fully charged, and one of the disadvantages of radiator cooling under these circumstances is the greater risk of overheating as compared with the more usual tank cooling system. Special steps are, therefore, necessary to reduce the risk of the radiator being short of water, and, for this purpose, arrangements are made to store water in a tank below the floor so that it can be pumped as required by a semi-rotary pump into the radiator until water is seen to spill from the overflow pipe on to the tray underneath the engine. As a further precaution, and in view of the difficulty of obtaining a supply of water in country districts, the rainwater gutters at the sides of the roof are connected by 1 in. pipes to the storage tank. It is, therefore, expected that there will usually be a supply of rainwater in the tank, and the instructions to the maintenance man are that he should always operate the hand pump to ensure that the radiator is quite full before starting the engine. The storage tank has a water level gauge, an overflow vent, and an additional orifice on the outside so that it can be filled from a bucket when necessary. A two-gallon petrol tank, accessible only from the outside, is built into the near side front corner of the floor and a petrol gauge is provided.

A Tungar rectifier for charging from the A.C. supply mains, when available, is also fitted at the forward end and charge-discharge working of the batteries is adopted no matter which type of charging unit is in use. The rear wall of the brakeman's cabin is utilised for two wood panels, one for mounting the supply company's main fuses and meters, and the other for the main switches and fuses controlling the Tungar rectifier and the lighting units.

FIG. 7.—MOBILE U.A.X. ON SITE.

Telephone Equipment.

The exchange equipment (U.A.X. No. 12) is housed in five totally enclosed units which are standard in every respect[2] except that the individual steel channel iron feet and wood mounting blocks have been replaced by two lengths of heavy channel iron extending the whole length of the five units. Rigidity is provided by bracing the tops of the units to both sides of the body. Each unit is constructed of a mild steel framework surrounded by a sheet steel cavity-walled cabinet and the removable doors at the front and back are clamped against rubber cord to make the unit airtight. The complete suite of five units forms a rectangular block 8 ft. 10 in. × 1 ft. 9 in. × 6 ft. 4 in. high, leaving 2 ft. 6 in. gangways at the front and back, 2 ft. at the ends and 8 in. clearance below the roof of the vehicle.

The units are in the following order, commencing from the rear end of the vehicle :—

- Auxiliary Unit (to which the telephone cable is connected).
- A Unit (for 25 subscribers)
- B Unit (for 20 subscribers)
- A Unit (for 25 subscribers)
- B Unit (for 20 subscribers)

Each of the subscribers' units is complete with a proportionate amount of junction equipment. The auxiliary unit has permanently connected to it a short length of telephone cable extending under the floor and terminating at a position on the rear wall adjacent to the incoming cable (Figs. **1** and **6**). On this wall is a demountable joint in which the pairs in the incoming cable can be jointed to those in the exchange cable, the whole being sealed against the ingress of moisture without the employment of plumbing operations. As this joint will be made and re-made fairly frequently, the end of the exchange cable will gradually have to be cut back, so the joint is bolted to a pair of vertical channel members extending from floor to ceiling. As first supplied, the exchange cable is of such a length that the joint is made near the ceiling, and as the exchange cable becomes shorter, the position of the joint is adjusted by two bolts. At some distant date, when the exchange cable has become too short, a new length of exchange cable will have to be installed. Fig. **1** also shows the shelf provided to accommodate the service telephone instrument.

Service.

The present mobile automatic exchange is definitely experimental, and for the purpose of proving the practicability of such a vehicle. Its first service has been the urgent replacement of a rural manual exchange at North Weald, Essex. Fig. **7** is a photograph of the Mobile U.A.X. on site and shows on the left, the overhead power supply, and on the right, the exchange distribution pole from which the lines are connected to the vehicle by a short length of underground cable. The replaced manual exchange was in the village Post Office, which is just visible on the left.

Although the first mobile automatic telephone exchange has been a product of the Post Office Circuit Laboratory, a special acknowledgment is made to Messrs. E. G. Brown & Co. for their contribution of ideas and interest in the many problems of meeting conflicting requirements. It will also be appreciated that the design of a self-contained mobile automatic telephone exchange has required the co-operation of many specialists, without whose willing assistance the work would have been seriously hampered.

[2] *P.O.E.E.J.* Vol. 28, p. 105.

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

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In this article, which is continued from the January issue, the cutting and lapping processes, by which quartz plates of the required dimensions are obtained from the raw material, are described together with details of the means adopted to determine accurately the directions of the crystallographic axes. In addition details of the resonator mounting system are given.

The Cutting Process

General.

BEFORE discussing the development of the cutting technique practised in the Post Office Engineering Department, it must be indicated that, for various reasons, the method differs considerably from the system employed by the lapidary and the optical worker. The lapidary makes a cut approximating to the desired plane and the required accuracy is obtained by manual or automatic grinding of the surface to the final form. With this sytem a high degree of cutting accuracy is not called for, the cutting operation is intermediate in obtaining the desired result, and the machine is of simple form and is comparatively rough ; a gravity feed is employed usually and the spindle speed is quite low, 300–350 r.p.m.

For the quartz crystal application the problem was considered to require a very different solution, economy of labour and material being primary considerations. To enlarge upon these two factors it was thought to be essential to obtain the highest accuracy practicable with a machine so that the maximum number of slices could be obtained from the slab and that individual trueing to the crystallographic axes of each slice—by lapping—would be eliminated. Two methods of cutting are practicable, the first using a soft metal saw continuously fed with the cutting material—generally carborundum granules—and the second using diamond fragments firmly embedded in the saw periphery. It was decided to use a lubricated diamond-charged saw, as it appeared that the application of abrasive material to a rapidly moving disc would not give the required precision.

A small lapidary's cutting machine was purchased in order to obtain the necessary experience, and the results of tests with this machine enabled an approximate specification for a high grade machine to be drawn up. Many cutting lubricants were tried in the preliminary tests and the final selection was a mixture of machine-bearing oil and paraffin oil in equal proportions.

Having drawn up a specification for a machine, which to the best of the authors' knowledge could not be obtained as a standard product, it was necessary to find a suitable machine into which the desired features could be built. After a prolonged search a plain hand-feed surface grinder was selected having a maximum capacity of 35 cm. by 15 cm. when using a grinding wheel 20 cm. diameter by 2 cm. wide.

The conversion of the surface grinder was carried out by the manufacturers to the Post Office specification, the work entailed being briefly as follows :—

The spindle was fitted with a special pulley incorporating a light spring-loaded friction device and driven at 1,500 r.p.m. This speed was much in excess of the value normally employed, but the initial experiments had shown that the increase would give an improved performance. A positive feed system was incorporated, the feed being adjustable in steps. It should be appreciated that, as far as the authors were aware, the idea of a positive feed was revolutionary at the time, but it was felt that precision cutting could be accomplished only if such a feed was employed.

Precision Cutting Machine.

The machine was designed to deal with crystals up to 10 cm. across the m faces and 20 cm. long, and to slice blocks of 12 sq. cm. cross section into plates 1·0 mm. thick and smaller blocks of 7 sq. cm. cross section into plates 0·5 mm. thick. A general view

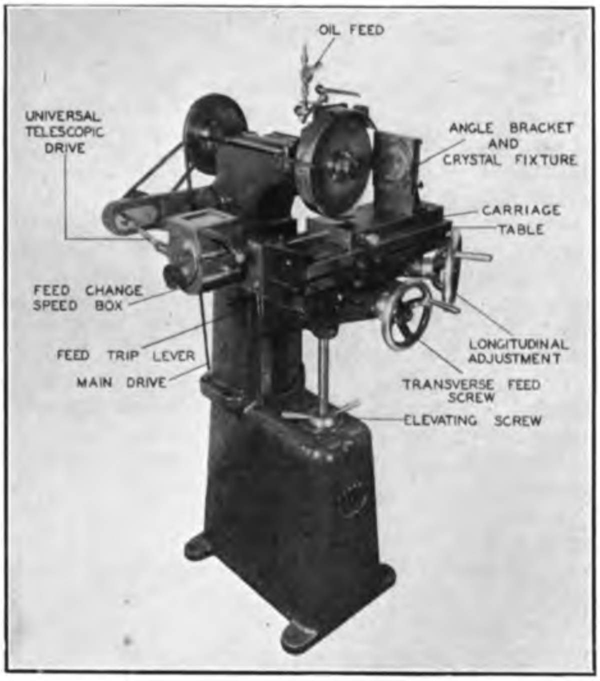


Fig. 13.—Cutting Machine.

of the machine is given in Fig. 13 and other more detailed views in Figs. 14 and 15. The main casting carries a ½ h.p. driving motor in the enlarged base, and the motor switch, of the push-button type, is mounted at the top of the column in a position for easy control by the operator.

The dovetail slides for the knee carrying the table and carriage are machined on the front surface of the column and the elevating screw supporting these parts passes through the forward projection of the

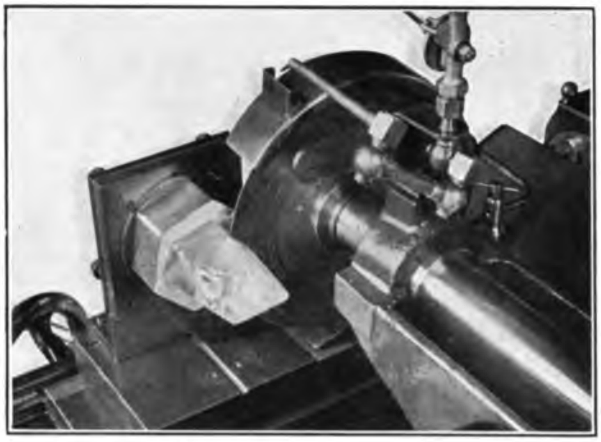


FIG. 14.—CUTTING Z SLABS.

base upon which the elevating nut rests. This nut is fitted with two handles for manipulation and is divided around the outer edge to show the elevation in thousandths of an inch. The longitudinal movement of the table which is used to bring the carriage and work up to the saw in preparation for cutting is operated by the large hand-wheel seen on the right (Fig. **13**) by a spiral rack and pinion. The transverse movement which controls the position of the cut, or in the process of slicing, the thickness of the slice, is operated by a feed screw controlled by the hand-wheel in the front of the machine and a micrometer collar on the screw indicates the movement in thousandths of an inch. Means are provided for locking all the movements of the table.

The spindle extension is fitted with loose packing collars to enable the position of the saw along the spindle to be varied. The spindle is of high grade steel running in substantial ball bearings, and is accurately ground parallel for the application of a precision spirit level in the process of setting up work on the carriage. The spindle runs at 1,500 r.p.m. and is driven through a friction device in which is incorporated the pulley for driving the carriage feed mechanism.

The table supporting the carriage and associated mechanism is deeply grooved around the top surface to drain away the used cutting lubricant, the grooves being sloped down to the back right-hand corner in which is situated a well and drain cock. The slide ways for the carriage are milled and ground on the top surface and take the form of a vee and flat.

FIG. 15.—CUTTING X PLATES.

The feed is controlled by an eight-speed gearbox, the eight feeds being arranged in geometrical progression from 1 to 5 inches per hour. The feed screw drive is obtained from the main spindle via a countershaft and a telescopic shaft, and in the event of the saw binding in the cut the friction clutch in the main spindle drive is operated and the feed is automatically stopped. The feed screw is driven from the gearbox through a multiple dog clutch which may be disengaged by the small lever seen on the right of the gearbox, or by an automatic stop mechanism. This mechanism may be set to operate at any point in the range of traverse of the carriage.

The carriage is of robust construction with a true surface grooved for accurate location of the angle bracket carrying the fixtures. The remaining portion of the upper surface is shaped for rapid draining of the cutting oil into the grooves in each side of the table. The machine is fitted with a splash guard for the cutting disc and a complete circulating system for the lubricant.

The fixtures, Fig. **16**, for holding the work, were designed to facilitate accurate positioning in three

(*a*) Z SLAB IN FIXTURE.

(*b*) FIXTURE PARTS AND Z SLAB MOUNTED ON GLASS DISC.

FIG. **16**.—FIXTURES FOR HOLDING THE WORK.

FIG. 17.—CHECKING MACHINE SPINDLE LEVEL WITH CLINOMETER.

planes mutually perpendicular to each other, as the surfaces of practically all plates and slabs are thus related. This condition was satisfied by making the fixture square and successively registering its sides against a horizontal shoulder on the angle bracket supporting it, and by locating the angle bracket in two positions mutually at right angles. Accurate positioning of the angle bracket was assured by a tongue on its base fitting into grooves cut in the upper surface of the carriage of the cutting machine. To enable an initial adjustment of the work in the fixture to be made and permit of angular cutting it was arranged to mount the work on a plate-glass disc fitted into a recess in the fixture body and secured by a circular clamping ring. Thus the quartz slab could be rotated until its crystallographic axes were in the desired relation to the sides of the fixture and therefore to the cutting planes. The fixture loaded with a Z slab is illustrated in Fig. **16a**, and the fixture components with a Z slab mounted on a glass disc are shown in Fig. **16b**.

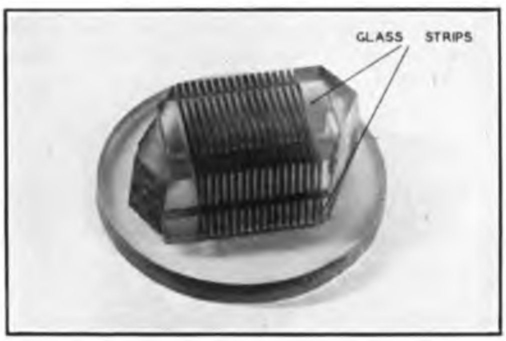
The method which has been adopted for setting up work in the machine makes reference direct to the spindle axis, thus obviating the use of intermediate surfaces which may in time lose their initial accuracy. The process is illustrated in Figs. **17** and **18**. In Fig. **17** the level of the spindle is being measured by a sensitive spirit level fitted to a divided arc reading in minutes. In Fig. **18** the level is being applied to a surface of the work which is very lightly clamped in the fixture. The base of the level has been turned through the required angle as read off from the vernier of the divided arc, and while the level base is held against the work they are both gently rotated until the bubble comes to rest between the two index lines. The clamping ring screws are then tightened and the work is accurately set to $\pm 0° 10'$.

FIG. 18.—SETTING UP Z SLABS WITH CLINOMETER.

Performance of the Machine.

The performance obtained with the machine demonstrated the value of the high spindle speed, and it would appear from experiment that an optimum value has been attained. The rate of cutting when using a 16·5 cm. saw enables a cut 4·5 cm. by 1 cm. to be made in 15 minutes and a 2·5 cm. by 2·5 cm. cut in 10 minutes, the quartz in each case being backed at the extremities of the cut with glass strips 4 mm. thick. The cut is 1 mm. wide for the 16·5 cm. saw and is always slightly tapered in the direction of feed because the saw clearance is small and slight vibrations or inaccuracies in the disc cause it to rub on the sides of the cut and so to produce a tapered cut. The effect of this wear upon slices is to make them wedge-shaped with the thickest end at the edge attached to the glass disc, the order of taper being some 0·01 mm. per 1 cm. depth of cut.

The thinnest 25 mm. square slice that has been cut measured 0·3 mm., but this is not considered a workable thickness as the material on either side of the cut is damaged by minute cracks which in such a thin slice may penetrate to the centre. It has been found good practice to adopt 0·6 mm. as the minimum



(*a*) X PLATES IN Z SLAB DIRECT FROM CUTTING MACHINE.

(*b*) X PLATES REMOVED FROM Z SLAB AND CLEANED.

FIG. 19.—SOME EXAMPLES OF CUTTING.

thickness, as when this is reduced to 0·4 mm. by lapping both faces, all imperfections are removed and, in addition, this thickness has been found sufficient to keep the breakage loss during cutting to an economic level. The surface of a cut is smooth and on close examination is found to be covered with fine saw marks which are very uniform due to the regularity of the mechanical feed. Some examples of cutting are shown in Fig. **19**. Fig. **19a** shows a prepared block from a Z slab mounted on a glass disc and completely sliced into X cut plates. The plates are still attached to the glass disc by the ceresine wax which is used to fix the Z slab to the glass disc and the glass strips used to steady the saw and hold the plate while the saw completes the cut are clearly shown. In Fig. **19b** a similarly sliced block is illustrated ; the plates and end pieces have been removed and cleaned, and the uniform penetration of the saw into the glass disc demonstrates the action of the automatic stop.

To summarise, the performance of the machine was found to be excellent in every way and the advantage of the precision over the lapidary's machine showed that the application of precision engineering methods to the problem had provided an excellent solution.

Production of Charged Saws.

Tests had shown that the saw material must be soft enough to enable it to be impregnated with diamond fragments without breaking the diamond and stiff enough to stand up to the work without fear of buckling. The thickness of the saw is limited due to the wastage of the material in the saw-cut ; this is particularly so in the process where plates are being sliced from Z slabs. It is thus necessary to effect a compromise between diameter, thickness and material of the saw. Many materials were tried before best-quality tinplate—tinned mild steel—was selected, the main factors governing the choice being the consistent high quality of " Primes " tin plate, its relative softness and the ease with which it could be worked.

Needless to say, several of the commercial " long life " type saws, i.e. saws in the form of flat discs with built-up rims, homogeneously impregnated with diamond dust, of thickness slightly greater than the disc thickness and some 1 to 2 cm. deep, were tested before the decision to produce saws was taken. All the early long-life saws failed due to lack of flatness ; recently, however, a new type has become available. The saw has distinct possibilities ; it is said to have a life of several thousand square cm. of quartz and a cutting speed of about 5 sq. cm. per minute.

For a given diameter of disc there is an optimum thickness which gives sufficient stiffness to maintain accuracy in cutting with reasonable economy of diamond and quartz. Experience has shown that the thickness for a 22·5 cm. diameter mild steel disc is about 0·70 mm., and for a 16·5 cm. diameter mild steel disc about 0·55 mm., using clamping plates, 7·5 cm. in diameter, in each case. In the early experiments much difficulty was experienced in producing true flat discs before the art of planishing was mastered.

Charging the discs with diamond was the subject of much experiment ; initially the diamond was applied and pressed into the periphery with a hard steel pestle, but discs so charged had a very short life and the lives of consecutive charges varied considerably. The life was not much increased by the substitution of a rolling process using a hardened steel roller, as the diamond was crushed too fine by the pressure applied. Both methods gave only a very small " set " to the saw, i.e. increase of periphery thickness, which soon wore off and caused the saw to bind in deep cuts. An attempt to provide more clearance was made by manually impressing fine radial notches round the periphery, the displaced metal projecting on each side, forming clearance, and the notches serving to hold a greater charge. The improved performance given by the notching indicated that more work should be done on these lines, and it was decided to make a machine to perform this operation.

The machine is illustrated by the photograph

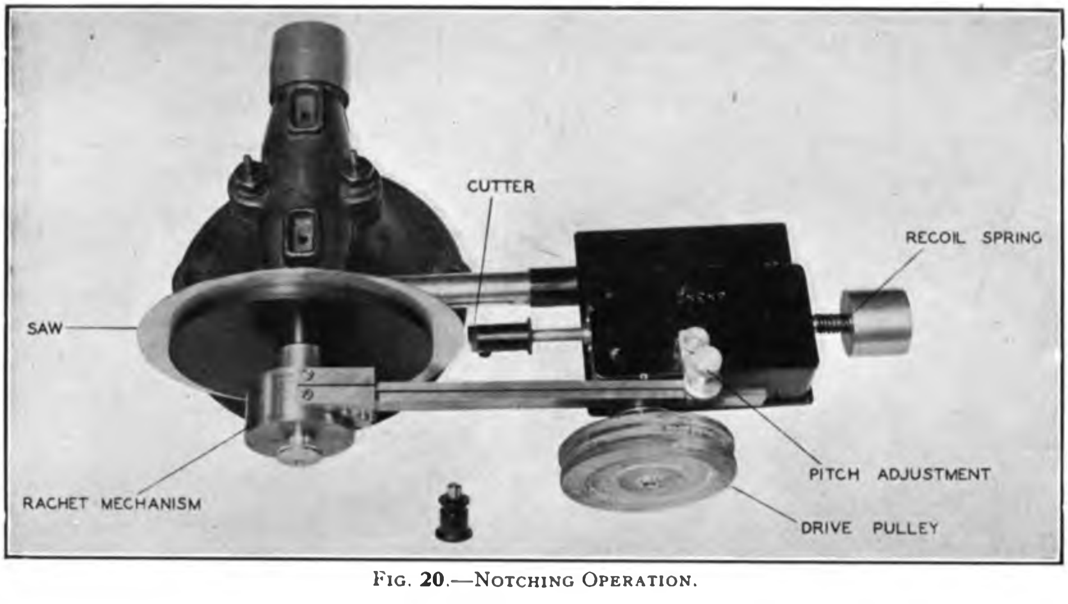


Fig. **20**.—Notching Operation.

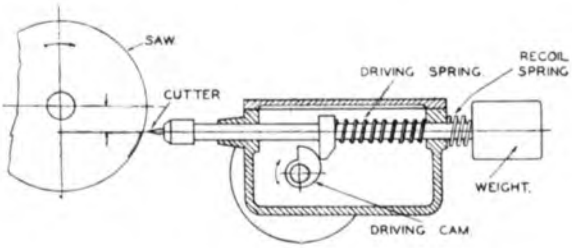


FIG. 21.—PRINCIPLE OF NOTCHING MACHINE.

(Fig. **20**) and the diagram (Fig. **21**). In principle it consists of a reciprocating cutter which is driven into the edge of the disc, thereby making a vee-shaped notch. The cutter is then drawn back ready for the next impulse, and the saw is automatically rotated slightly. When the next notch is made some of the metal displaced partly closes the previous one, which thus becomes more parallel-sided and is better suited to retain the diamond fragments. This procedure is repeated until the saw is completely notched. The pitch of the notches is continuously adjustable. The photo micrograph, Fig. **22**, illustrates examples

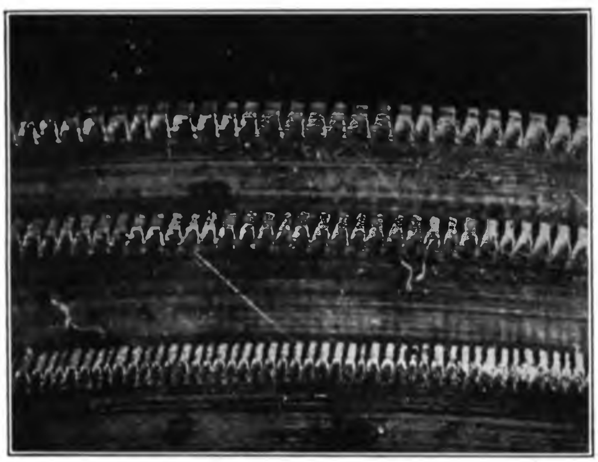


FIG. 22.—NOTCHED SAWS (8 TIMES FULL SIZE).

of notching magnified 8 diameters, three different pitches are shown and the partial closing of the notch may be seen. The regularity and uniformity of notching produced is clearly shown.

The charging operation, as practised at present, consists of notching the saw, preparing the diamond fragments, applying them to the saw, and partially closing the notches to retain the charge. If it is desired to recharge an old saw, the notching process is not carried out until the old charge has been removed. In the preparation of the diamond fragments it is important to ensure that they are uniform in size and suited to the diameter and thickness of the saw. The fragments are mixed with petroleum jelly for convenience of application and are well pressed into the notches, the surplus being collected and re-applied. When it is considered that sufficient diamond is retained by the notches the edge is rolled with a hard steel roller as shown in Fig. **23**. The two large flanges between which the saw is held prevent

FIG. 23.—DIAMOND CHARGING OPERATION.

buckling and hold the saw true. During the rolling operation the notches are partially closed, thereby gripping the diamond fragments and at the same time a slight spreading of the edge occurs which increases the side clearance of the cutting edge, i.e. the set of the saw.

THE LAPPING PROCESS

General.

The art of lapping is a highly skilled one which can be mastered only by long and arduous practice. It is not proposed to discuss the many artifices which must be used by the operator in producing true, flat surfaces. It can be stated, however, that optical flats which are necessary for certain processes practised in the Crystal Laboratory can now be made without undue difficulty.

Circular close-grained soft cast-iron lapping plates were standardised, and both rotary and fixed laps are employed. Several cutting abrasives were used in the preliminary stage before the most suitable was adopted. To minimise erosion of the laps a weak soda solution is used as the lubricant. Rotary laps (Fig. **24**) are used for rough work and the hand laps

FIG. 24.—GRINDING SLAB ON ROTARY LAP.

for finishing. The methods employed in lapping the resonators to the specified dimensions are outlined in the section dealing with Production.

Maintenance of Lapping Plates.

The maintenance of a truly flat surface on the lapping plate is essential for accurate work. With constant use the plate tends to become hollow in the centre due to the motion of the work over it, and in practice this is counteracted by the use of a suitable stroke. The proportions of the stroke can be decided only by experience which will show the modifications which produce a concave or convex surface, and the intermediate stroke may then be adopted.

The truing of the lapping plates may be accomplished by arranging them in sets of three which are then lapped together in pairs until they are all flat. The order of lapping, numbering the plates 1, 2 and 3, is as follows :—

2 on 1, 3 on 1 ; 3 on 2, 1 on 2 ; 1 on 3, 2 on 3, etc., etc. This is repeated, using a fine abrasive, until any pair of plates show contact all over when rubbed together dry.

Determination of the Directions of the Crystallographic Axes

It is essential in the production of resonators that the plate orientation with reference to the crystallographic axes agrees with the specified orientation within very narrow limits. In consequence a technique for the precise determination of the directions of the axes is a necessary part of the process.

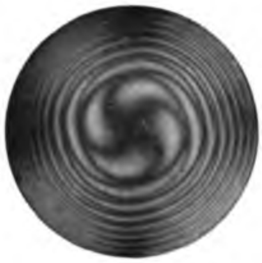
Determination of the Z Axis

Reference has already been made to the fixity of the inter-facial angles of the natural crystal, and when a crystal possesses at least three clean unstepped R and/or z faces the Z plane is obtained within fairly close limits by reference to these faces. The angle which the R and z faces subtend to the Z axis is 38° 13′. For crystals which do not possess the pyramid faces, and the employment of such crystals increases greatly the supply of raw material, another reference system based on the bi-refractive property of quartz is employed.

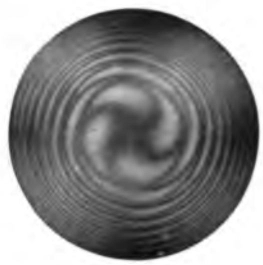
A curious phenomenon is observed when a slab with polished ends truly perpendicular to the Z axis is examined in convergent polarised light. If a monochromatic light source is employed and the nicols are crossed then, when the slab is inserted in the field, the Z axis of the slab being coincident with P, the axis of the instrument, the quartz is illuminated due to the rotation of the plane of polarisation and, in addition, a series of dark rings appear, the rings being crossed by two dark bands at right angles (Fig. **25a**). Rotation of the crystal about its Z axis has no effect on the figures which remain stationary. Rotation of the analyser, however, causes the cross to rotate in unison, and the concentric ring system expands or contracts according to the direction of analyser rotation and to the hand of the quartz.

Should the slab be tilted slightly to displace the central incident ray from parallelism with the Z axis, the centre of the ring system moves away from the axis of the instrument along the line of intersection of

(*a*) L.H. or R.H. Crystals (Single Light Transmission)



(*b*) L.H. Crystal (Double Light Transmission).



(*c*) R.H. Crystal (Double Light Transmission).

Fig. **25**.—Interference Patterns for Trued Z Slabs in Polarised Convergent Monochromatic Light.

the ZP plane (the plane containing the Z and P axes), with the slab and at the same time the pattern is distorted, being closed up in this line. When an untrue slab, i.e. a slab in which the axis Z′ is not parallel to the true Z axis of the crystal, is examined, similar effects are observed, and the direction of the ZZ′ plane can be determined. Rotation of the untrue slab about its Z′ axis causes the rings to move slightly, owing to their eccentricity and distortion, the amount of movement being a function of the angle ZZ′. Thus if the instrument axis is parallel with the Z axis of the slab a stationary pattern is obtained when the slab is rotated about its Z axis ; but should the two axes not be coincident the pattern moves on rotation of the slab about its Z′ axis, and an optical system of axis determination is available.

It is beyond the scope of this article to embark on a detailed discussion of these properties. Briefly, a plane polarised ray incident on the slab in any direction, other than along the Z axis or at right angles to it, is split into two components, owing to the two refractive indices of quartz, ω and ϵ for vibrations parallel to and at right angles to the Z axis. Each of the components suffers a retardation proportional to its refractive index and the concentric dark rings are produced by the interference of the two rays. The two components of the dark cross indicate the directions of the vibrating planes of the analyser.

To obtain the maximum sensitivity a modified form of the optical system which has been described is employed (Fig. **26**). Convergent plane polarised monochromatic light incident on the test slab is reflected back through the slab to the analyser. The

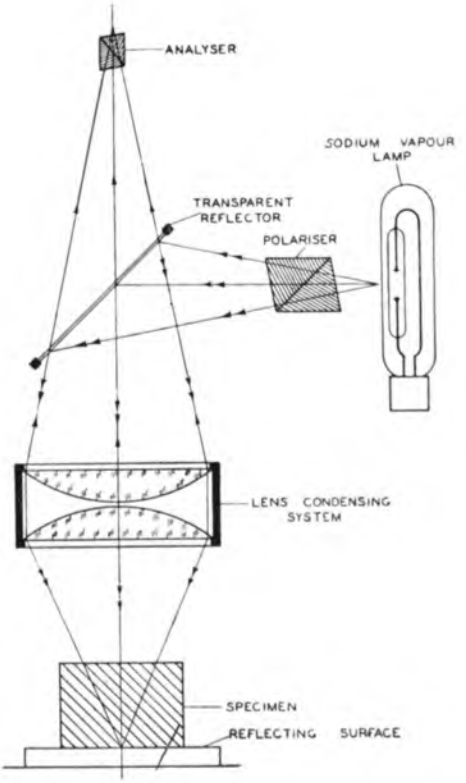
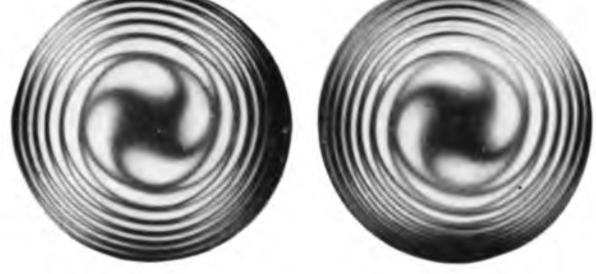
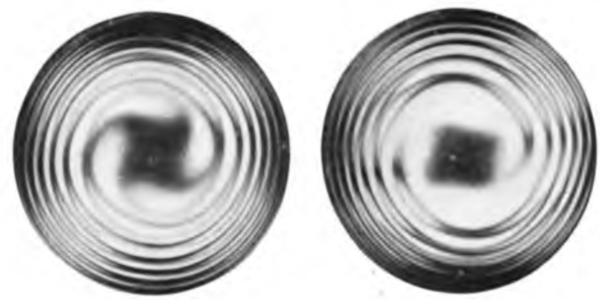


Fig. 26.—Polariscope—Convergent Light System.



Angle of Tilt : Zero. Angle of Tilt : 10 Minutes.



Angle of Tilt : 20 Minutes. Angle of Tilt : 1 Degree.

Fig. 27.—Interference Patterns for a Trued Z Slab in Polarised Convergent Monochromatic Light.

instrument uses a sodium vapour lamp light source, and nicols are employed for both polarisations. The sodium light is passed through the nicol polariser to a 45° transparent screen from which it is reflected on to the specimen. The necessary convergence is given by a condenser placed between the screen and specimen. The light is reflected from the underside of the slab by a mirror and is transmitted through the lens system and screen to the nicol analyser through which the interference pattern is observed. The specimens and mirror are mounted on a rotatable table and the condenser is movable in a vertical direction to allow the convergent ray to be focused on the mirror. The light traverses the slab twice, in opposite directions, and the resulting pattern is identical with that obtained when two trued slabs of the same thickness and of R. and L.H. quartz respectively placed one on the other are examined in apparatus described previously. The pattern is the well-known Airy's spirals. Figs. **25b** and **c** show the patterns for L.H. and R.H. crystals. When the slab and instrument axes are parallel, the pattern possesses quadragonal symmetry about Z, and rotation of the slab about Z has no effect upon the figure.

If the two axes are not parallel the pattern is distorted and rotation of the slab causes the pattern to move. The direction and sense of an error can readily be determined by tilting the slab until the true pattern is obtained. The accuracy of the instrument is demonstrated in a beautiful manner by the photographs of Fig. **27**, which show the patterns of a true slab, 2 cm. thick, as the slab is tilted from the position of parallelism for Z and P to three positions giving angles of 0° 10′, 0° 20′ and 1° 0′ between Z and P. The order of accuracy to which it is possible to define Z is within ± 0° 5′.

Procedure of Trueing a Z Slab to the Z Axis.

The Z′ planes of the slab which have been made accurate to within some ±0° 30′ in the cutting process are lapped flat and approximately parallel. The slab is mounted between thin glass plates wetted with toluol—it is not practicable to use a bath—and is set on the table of the instrument. The approximate order of the slab's inaccuracy is then observed by rotating it about Z′. The slab is next set in one of the two positions in which an imaginary line crossing the pattern in the direction of least distortion is parallel to the zero line marked on the table and is rotated about this line until the true pattern is obtained. The amount of the rotation is a function of the slab's error, and the Z′ plane nearer to the mirror is lapped in successive stages to correct the inaccuracy. When the Z′ axis of the slab approaches parallelism with the instrument's axis, it is advisable, before the final adjustment is made, to true the other Z′ plane of the slab, i.e. to make the two Z′ planes parallel. If this is not done at this stage, then although the two axes are parallel, the pattern will rotate with rotation of the slab due to the different lengths of the corresponding light paths in the slab.

Specimens with z dimensions in the range 0·2 to 10 cm. are successfully handled by the instrument. It is not practicable to work with thinner slabs, owing to the large spacings which are obtained between the concentric rings of the pattern. The operation is not affected appreciably by a small amount of optical twinning, which merely breaks up the pattern locally and gives rise to a slight "blurr." The time of the process is dependent on the skill of the operator, but in general it is less than 20 minutes.

Determination of the X Axes.

This presents a much more difficult problem than that for obtaining the Z axis, although several methods of approach are available. The first is one in which the X axes are referred to the m crystal faces, and is, of course, applicable only to crystals which possess one, and preferably more, good prism faces. Even in Z slabs from the most irregular crystals, at least one, and usually three or more of the horizontal edges of the m faces are straight and good, and the X axis direction is determinable from these edges to within $\pm 0° 10'$.

In the second method, the trued Z slab is etched on a Z plane. The etch pattern of an untwinned slab comprises a mosaic of small rhombohedra, the axes and faces of which are fixed with reference to the crystallographic axes so that corresponding rhombohedral faces are set in parallel planes. The slab is mounted on a table, capable of rotation, with the etched plane upwards, and a beam of light parallel to the Z axis of the slab is arranged to fall on the etched plane. The light is reflected from the three sets of elementary rhombohedral faces to form three beams 120° apart. Thus when the table, which is fitted with an angular scale, is rotated, three positions of maximum intensity, 120° apart, are apparent to a fixed observer, each one of these directions being parallel to a Y axis. Unfortunately it has not been possible to obtain a high order of accuracy with this system because the rhombohedral faces are slightly curved, the amount of the curvature being dependent on the rate and period of etching. The directions of maximum reflection are thus effected by the etching process.

The third method, which is no doubt capable of a very precise determination, employs an X-ray spectrometer to locate definite crystal planes by the reflection of X-rays at these planes. To the present, the authors have not employed this system, and in their opinion the complicated nature of the equipment renders the production of an instrument capable of being used by semi-skilled labour, i.e. a workshop tool, an extremely difficult problem.

The fourth method, which in the opinion of the authors is the best and most practicable, employs the pronounced cleavage which exists in a thin Z slice. When the specimen is fractured by mechanical stress set up by temperature gradients, three distinct cleavage planes are obtained which are respectively parallel to the m faces, and the X axes are determinable to within $\pm 0° 5'$ by reference to these directions. It is then a relatively simple matter to replace the slice on the natural crystal and so determine its X axes without further question of accuracy.

Determination of the Y Axes.

As the X, Y and Z axes form a system of right-hand rectangular co-ordinates, the Y axis is known when the other two are known.

RESONATOR HOLDER

The oscillation frequency of a quartz vibrator is determined primarily by the constants of its equivalent circuit, although the mounting system has a secondary effect on the frequency, inasmuch as it changes this equivalent circuit. Thus, in order to take full advantage of the high order of constancy obtaining in the equivalent circuit of the crystal, due consideration must be given to the holder design to ensure that it does not introduce either a variable or appreciable damping into the circuit.

In the filter application it is desirable to fix rigidly the value of the capacitance across the resonator, and this is accomplished by making the electrodes contiguous to the X plane surfaces. The comparatively large number of resonators required, 1,408 including spares, in the first instance, rising to some 10,000 when the London-Birmingham coaxial cable is completely equipped, made it necessary to consider the possibility of obtaining a mass production article in accordance with the following design considerations :

(*a*) The design to be identical for all the resonators, to be compact and to permit of panel mounting.

(*b*) The plate to be clamped in such a way as not to affect appreciably the decrement of the equivalent circuit and the clamping system to be sufficiently robust to permit of transport of the mounted resonator.

(*c*) The design to permit the holder to be hermetically sealed to avoid a breakdown of the insulation between the two electrodes.

(*d*) The design to enable the series resonant frequency of the plate to be adjusted to within ± 10 c/s of the specified value, the final frequency adjustment being made on the mounted resonator.

Several types of holder were constructed and tested before the final design was evolved, although they were all alike insomuch that the plate was clamped in its nodal plane between spring contacts, the spring and contacts being used to provide the electrode connections. The final design is shown in Fig. **28**. The plate is clamped between four hemispherical gold-silver contacts, riveted on two split phosphor-bronze springs, the springs being split to allow of the automatic alignment of the contacts. The springs are

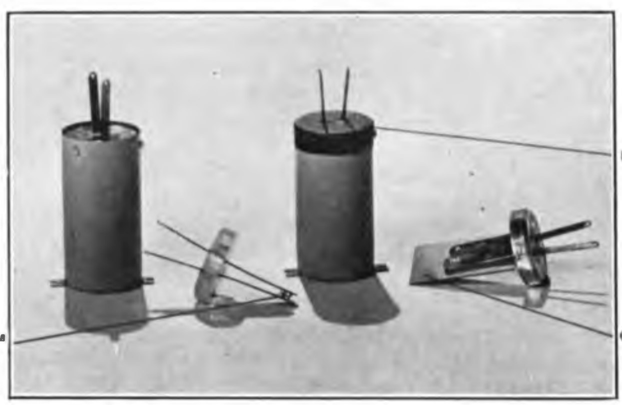


FIG. **28**.—HOLDER FOR CRYSTAL FILTER PLATES, 60-100 KC/S.

moulded in a trolitul disc which is mounted in a spun copper container; a bayonet fitting is employed, and the spring projections through the disc serve as soldering tags. Brass lugs soldered to the base of the case enable the holder to be mounted on the vertical panel so that the X plane surfaces of the crystal aıe horizontal.

It will be observed that the nodal plane of the Y wave is not parallel to the Z axis of the plate but subtends an angle of 19° to this axis ; it is parallel to the X axis and bisects the X plane faces. It is, of course, possible to set the resonator in the holder so that the angle between the Z axis and the contact line is in the wrong sense. When the sign of the angle is incorrect, however, the effect on the decrement of the plate is obvious, and it is usual to determine the correct position by trial.

The design is compact and accommodates the entire range of resonators, the external dimensions of the case being 2·75 cm. diameter by 6 cm. long. The mounting system allows the series resonant frequency to be adjusted to within $\pm$ 10 c/s of the specified value and permits the final frequency adjustment, obtained by lapping the y dimension, to be accomplished while the resonator is mounted. The contact pressure on the crystal is adjusted so that normal jars and vibrations do not cause it to move relative to the contacts.

Much trouble was experienced in the initial experiments from the deposition of moisture on the Z and Y plane faces which has been known to reduce the insulation resistance between electrodes to less than 1 megohm, as measured with a 10-volt battery and a micro-ammeter. The minimum working value of this resistance was found to be some 100 megohms and many sealing systems were tried before a satisfactory seal was obtained. The resonator and holder are carefully dried, the mounted resonator is located and locked in the case, and a special sealing compound is poured into the top of the holder which is completely flooded. When the compound is partially set, the holder is inverted and dipped into a bath of the compound to a distance of about 0·5 cm. below the top of the case, the top of the tags being protected during the latter part of the process. This method gives a clean positive seal of the mould in the case and also serves to seal any faulty soldering of the bayonet pins in the case.

TELEGRAPH AND TELEPHONE PLANT IN THE UNITED KINGDOM
TELEPHONES AND WIRE MILEAGES. THE PROPERTY OF, AND MAINTAINED BY THE POST OFFICE IN EACH ENGINEERING DISTRICT AS AT 31st DECEMBER, 1938.

Number of Telephones	OVERHEAD WIRE MILEAGE					Engineering District	UNDERGROUND WIRE MILEAGES					
	Telegraph	Trunk	Junction	Exchange*	Spare		Telegraph	Trunk	Junction‡	Exchange†	Telephone Spares	
											Trunk	Junction ‡
1,162305,	324	540	1,572	57,479	5,856	London	24,077	320,462	909,382	3,244,721	89,330	307,446
145,186	1,541	1,416	11,130	56,905	13,173	S. Eastern	5,778	136,072	23,718	389,098	58,128	21,730
173,159	1,835	10,422	26,086	112,273	101,42	S. Western	19,734	145,812	14,182	348,701	70,468	16,369
123,470	2,474	9,397	23,058	88,451	20,673	Eastern	7,695	163,568	18,672	256,436	106,752	16,640
142,684	3,102	11,284	18,156	73,455	27,241	N. Midland	9,325	224,906	23,101	292,516	90,904	23;318
160,651	1,657	5,305	17,157	82,324	20,296	S. Midland	9,824	200,818	36,764	410,939	76,168	34,320
83,592	1,138	5,376	17,226	59,186	12,156	S. Wales	5,674	86,318	17,154	159,097	63,138	14,970
209,512	1,606	9.242	23,522	90,362	18,924	N. Wales	12,647	230,214	103,756	450,379	111,324	40,248
246,530	971	1,530	3,148	36,323	5,398	S. Lancs	10,389	130,808	107,818	696,962	69,054	57,396
103,815	713	2,048	5,052	37,683	14,195	N. Western	5.937	127,294	20,486	272,129	98,184	14,140
40,960	2,891	6,450	6,592	190,98	1,148	N. Ireland	1,589	14,158	7,858	89,551	26,608	4,924
297,099	4,605	12,749	22,763	103,720	30,878	N.E. Region	17,499	263,414	74,108	726,891	211,128	46,027
275,689	6,130	23,416	32,368	104,058	27,160	Scot. Region	10,456	213,368	38,630	538,606	150,812	34,994
3,164,652	28,987	99,175	207,830	921,317	207,240	Totals	140,624	2,257,212	1,395,629	7,876,026	1,221,998	632,522
3,110,872	29,622	103,086	210,803	899,944	205,285	Totals as at 30 Sept., 1938	140,737	2,193,882	1,355,915	7,738,017	1,151,960	640,317

* Includes low gauge spare wires, i.e. 40 lb. † Includes all spare wires in local underground cable. ‡ Wholly Junction Cables.

Rugby Radio Station

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U.D.C. 621.397.71

The growth of services carried out through the Post Office radio station at Rugby is reviewed. A brief description is given of the plant installed at the station, which now includes thirteen radio transmitters and over forty aerials. Some notes on possible future developments are added.

Introduction.

THE Rugby Radio Station was described, soon after it came into being, in a paper presented to the I.E.E. in 1926[1]. At that time, the station housed only one transmitter. Since 1926, the scope of the services through the Rugby Station has so increased that the station now contains no fewer than 13 transmitters of various types. Although articles have been published from time to time, dealing with individual aspects of these installations, an up-to-date review of the main features of the station may be of interest.

Growth of Services Operated Through the Rugby Station.

The Rugby station was opened on January 1st, 1926, for the transmission, on a long wavelength and with extremely high-powered equipment, of telegraphic messages to the more remote parts of the world, which could not be reached by the then existing lower-powered transmitting equipments installed at the Post Office stations at Leafield and Northolt. This service of telegraphic messages is still continued and includes, among other items, transmissions of the official British Foreign Office press and other broadcast news bulletins to the colonies and to many of the principal countries in the world, standard time-signals which are relayed from Greenwich Observatory and which are intercepted by ships of all nationalities, and telegrams to ships in all seas. To supplement this telegraphic service over shorter ranges, a lower-powered medium-wavelength transmitter was added in 1928, and is principally employed in sending telegrams to continental countries.

A year after the Rugby station was opened, an important milestone in the development of telecommunication services was passed by the opening to the public of a telephone service to the U.S.A. This was rendered possible in part by the installation of a powerful long-wave radio transmitter at Rugby, by which the speech signals from telephone subscribers in this country were relayed across the Atlantic. At that time, the technical position of the radio art was such that only long wave-lengths could be used for such transmissions; but investigations into the behaviour of short waves, coupled with a demand for more than one "trunk" telephone circuit to New York, resulted in the addition in 1928 and 1929 of three additional short-wave transmitters, by which three further circuits were provided. The successful employment of short-wave radio telephony to U.S.A. led to an investigation of the possibility of extending the telephone service to the principal colonies and to other important countries which could not, for technical and economic reasons, be provided with a service by submarine cable. As a result, in 1930, services were opened to Australia, to South America and also to certain liners on the North Atlantic route; in 1932, services were opened to South Africa, Canada and Egypt, and further services were inaugurated to India (1933), Japan (1935), Iceland (1935), Kenya (1936), and Portugal (1937), this last arising from interruption of the normal land-line telephone circuits due to political trouble in Spain. A further service to China, which was envisaged for 1937, has not been brought into use as a result of the disturbances in China. These various services were provided by the addition, in the years 1930-1934, of five further transmitters at Rugby, all operating on short wavelengths. It will be apparent that the number of services initiated considerably exceeded the number of transmitters which was provided. This was rendered possible by the fact that overlapping business periods in Britain and Eastern countries occur during the morning (British time) and in Britain and Western countries during the afternoon. As a result, it was possible to utilise a transmitter for sending messages for example, to Japan during the morning and to South America during the afternoon and evening. This arrangement led to considerable savings in plant; but more recently general expansion in telephone traffic gave rise to demands from certain colonies for longer-period services than could be provided by only part-time use of the necessary equipment. At the same time, further advances in technique had revealed the possibility, for the short-wave circuits to New York, of utilising the single sideband system of transmission, which, in addition to improving the grade of service, also opened up the possibility of sending two conversations simultaneously from a single transmitter. These circumstances resulted in a decision to erect two further transmitters at Rugby in 1937 and 1938, designed to operate on the single sideband system, each equipped for simultaneously handling two conversations. The introduction of these into service permitted the diversion of two of the older, single-channel transmitters, formerly used on the U.S.A. service, to extend the periods of service given to other countries.

An important and increasing service, which is carried out by the short-wave telephone plant, is the distribution of programmes to the colonies and to other countries for re-broadcasting in these countries. The programmes are transmitted over the commercial circuit to the appropriate receiving station on short-wave-lengths, and from there are passed to the local medium-wave broadcasting transmitters.

The result of the expansion is that, through the Rugby station, in addition to the telegraph facilities afforded, it is possible for a telephone subscriber in this country to establish speech contact with about 25 million other telephone subscribers situated in extra-European regions. As an indication of the amount of traffic handled, it might be mentioned that,

[1] *I.E.E.J.*, June, 1926.

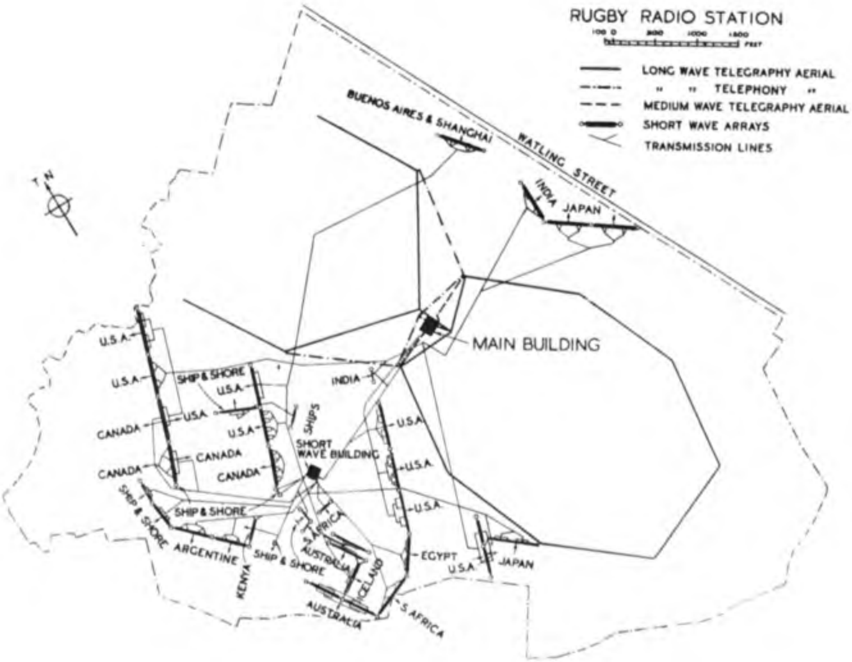

FIG. 1.—SITE PLAN.

during the week ended October 1st, 1938, 1,881 overseas telephone calls, totalling about 11,400 minutes' traffic time, 63,000 words of press and over 3,200 radio telegrams, in addition to numerous time-signals, etc., were passed through the station. In addition, 34 special programmes destined for re-broadcasting in other countries, and occupying a period of 629 minutes, were transmitted.

Site and Buildings.

The site has an area of approximately 900 acres situated four miles to the south-east of Rugby town. Two main buildings are provided. The first contains the long and medium-wave transmitters and two short-wave transmitters in an annexe. The second houses the remaining short-wave transmitters. The layout of the site is shown in Fig. 1.

Power Supplies.

Electric power is obtained from the Leicestershire and Warwickshire Electric Power Company through 12,000 V, 3-phase, underground cables. In order to minimise the risk of a power failure, separate feeders, each capable of supplying the whole load of the station, are provided from the Company's two stations at Hinckley and Warwick. Before use, the incoming supply is stepped down either to 2,200 V or 416 V, the former being used to operate four large synchronous motors, which drive the high tension D.C. generators used in conjunction with the long-wave transmitters, and the latter for all the remaining miscellaneous supplies. By suitably over-exciting the synchronous motors, they are caused to take a leading current which balances the lag produced by the numerous induction motors, transformers, etc., on the station, thus giving an overall power factor of unity for the station. The total annual power consumed is about 5,500,000 units.

Water Supplies.

An important requirement at the station is an adequate water supply for cooling the anodes of the transmitting valves as these dissipate a total of some 700 kilowatts in heat when all equipments are transmitting simultaneously. Owing to the adverse action of impurities in water on the anodes of transmitting valves, distilled water is used for circulation through the valve water-jackets. This distilled water is in turn passed through coolers, where the heat is extracted by the circulation of water at the rate of some 140 galls per minute from a reservoir containing some 500,000 gallons which was constructed on the site.

Transmitter Power Supplies.

High-tension D.C. Systems. The valves in the various stages of the transmitters utilise anode D.C. voltages which vary from 150 V for the small receiving type of valves in the frequency-generating stages to 12,000 V for some of the larger-powered amplifying valves. Although, in some of the later transmitters, copper-oxide rectifiers are used, in conjunction with constant voltage transformers and suitable output smoothing filters, to provide voltages up to 3,000 V, such voltages are obtained in the majority of cases from D.C. machines, which are provided with choke-condenser filters to reduce fluctuations due to commutator ripple. For the long-wave transmitters, the 12,000 V D.C. voltage required for the main valves is also obtained from D.C. generators. One such machine, used with the long-wave telephone transmitter, consists of a 640 kVA, 2,200 V, 3-phase, synchronous motor, which is directly coupled to two 250 kW, 6,000 V, D.C. generators, the outputs of which are connected in series. The D.C. machines are provided with specially-designed high-speed circuit-breakers, as high-powered transmitting valves are subject on occasions to " flash-arc " discharges, under which conditions the normally high insulation resistance between anode and cathode completely breaks down and the valve in consequence acts as a short-circuit across the high-tension D.C. anode supply. Although normally such a condition is taken care of by the circuit-breakers, it is of interest to note that the D.C. machines are themselves designed to withstand without damage, a dead short-circuit, under which condition the normal full-load current may increase tenfold.

The medium-wave transmitter and all the short-wave transmitters utilise A.C. rectifying systems to provide the high tension supply, each transmitter being equipped with its own rectifier. Some of the older equipments use water-cooled diodes in a hexaphase connection as rectifying agents. The later transmitters utilise either hot-cathode mercury-vapour tubes or glass envelope cold-cathode mercury arc bulbs, the main advantage of these systems lying in the lower anode potential required to give saturation current, with consequent improved efficiency and greatly improved voltage-regulation, compared with that of the evacuated thermionic diode device. Since it is convenient to have the voltage of the main high tension D.C. supply variable, the transformers supplying the thermionic and mercury-vapour valve rectifiers are fitted, on the primary side, with induction regulators ; while in the mercury arc rectifiers, regulation is effected by A.C. voltage control on grids which are inserted between the anodes and the mercury-pool cathode, this having the effect of limiting the period during which current passes. A photograph of a mercury arc rectifier is shown in Fig. **2**. This rectifier is rated to deliver a normal output of about 60 kW at 12,000 V, with a conversion efficiency, including that of the associated transformer of about 94 per cent. and a voltage regulation, from no load to full load, of only 3.5 per cent.

Grid Bias Supplies. The grid bias supplies to the transmitting valves are normally provided from motor-generators, since voltages up to 600 V may be required and an appreciable current may be passed when the transmitting valves are fully excited.

Filament Supplies. The filaments of the valves in the long-wave transmitters are heated by alternating current, regulators being provided to prevent fluctuations on the incoming supply voltage being reflected in the voltage supplied to the filaments. The filaments of the transmitting valves in the short-wave

FIG. 2.—MERCURY ARC RECTIFIER, 60 KW, 12,000 V.

telephone equipments are heated by direct current supplied from motor generators.

Transmitting Valves.

"Sealed-off" Valves. All the transmitters on the station employ thermionic valves throughout in the high-frequency stages. The majority of these valves are of the conventional pattern which, after the air has been evacuated, are permanently sealed. They range from small receiving-type valves, handling a power of a few milliwatts, to large power amplifying valves, capable of converting D.C. powers in excess of 100 kW into high-frequency energy. The largest radiation-cooled valves employed are capable of dissipating a power of 1·5 kW at the anode and have envelopes of special heat-resisting glass. Above this power, the anodes are cooled by the circulation of water, by which means a power of 100 kW can safely be dissipated at the anodes in some of the largest valves employed.

Demountable Valves. A feature of the Rugby station is the use, in several high-power amplifiers, of valves of demountable type. In this class of valve, which was developed by Messrs. Metropolitan Vickers Electrical Co., Ltd.[2] in collaboration with the Post Office, the electrodes are supported from flat annular rings of copper, which are optically-ground flat. In order to obtain the necessary insulation between electrodes, cylinders of porcelain are interposed between the electrodes and the whole is assembled by stacking the electrode-supporting rings and insulating-spacers, one above the other, on a base below which is mounted the air pumping equipment. The joints are smeared with a special, low vapour pressure grease, this providing a satisfactory pressure tight joint, and the air is continuously evacuated by a condensation pump, using special low vapour pressure oil as distillant, which, unlike the usual mercury pump which requires liquid air for condensation, can be condensed by a circulation of cold water round the pump jacket. The condensation pump is backed by a coarse mechanical pump, and a valve, after being open to atmospheric pressure, can be evacuated to a pressure of 10^{-6} mm. of mercury in the course of about 2 hours. The advantage of this type of valve is that, when the filament burns out, the valve is not scrapped as with a normal "sealed-off" valve, but can be dismantled, the filament replaced, re-assembled, re-evacuated, and thus restored to service. One demountable triode in use at the station is capable of handling, on long waves, a power of about 250 kW. Another type of demountable valve used in the later short-wave transmitters, is of the 4-electrode type, each valve of this type being capable of handling a power of some 60 kW on short waves and two such valves being mounted on a common pumping equipment. A photograph of one of these valves, *in situ* in a short-wave transmitter, is shown in Fig. **3**.

Long-wave and Medium-wave Telegraph Transmitters.

The main long-wave telegraph transmitter—call-sign GBR—working on a wavelength of 18,750 metres (16 kc.p.s.) was described in detail in the

[2] *I.E.E.J.* July, 1935.

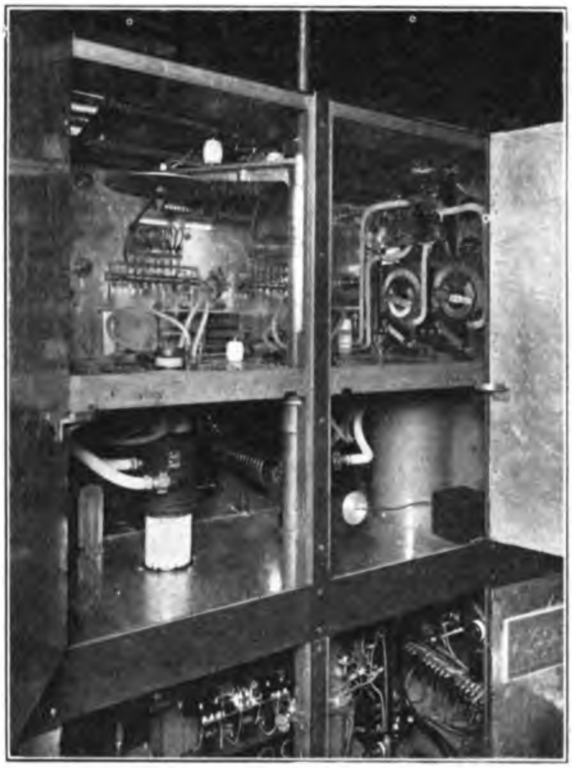

FIG. 3.—DEMOUNTABLE VALVE IN SHORT-WAVE TRANSMITTER.

I.E.E. paper on Rugby already mentioned, and has only been modified in small details. This transmitter, which was designed and constructed by the Post Office Engineering Department, and which is capable of delivering a high-frequency power of about 500 kW to the aerial, is believed still to be the highest-powered radio telegraph transmitter in the world using thermionic valve power amplifiers. The main features of this transmitter are the use of a valve-driven tuning-fork to generate a standard frequency from which the emitted radio-frequency is derived, and the use of two or, at times, three banks of 18 water-cooled 10 kW valves in parallel in the final amplifier. As an alternative to one of the banks of 18 water-cooled valves, a single valve of demountable type, capable of handling a power of 250 kW, is used. It is of interest to note that the ratio of output power to input power in the chain of amplifiers operating on the final radio frequency is of the order of 50,000,000: 1—77 db.—without recourse to special neutralising circuits in the amplifiers. The radiation of the signals during "keying" is controlled entirely by a small relay inserted in the grid circuit of a valve at a point where the radio frequency power-level is less than 1 watt.

The medium-wave telegraph transmitter is to some degree a miniature replica of the GBR set. It is of considerably lower power output (30 kW), works on a wavelength of 3,846 metres (78 kc.p.s.), and is equipped with facilities for high speed transmission. Only three water-cooled valves are used in the final output amplifier, the frequency being again derived from a valve-driven tuning fork.

It is perhaps noteworthy that the two telegraph transmitters, although situated in different rooms, are attended by only one man who, from his control-desk, is able to monitor the output of each transmitter and assure himself of the proper functioning of the equipments. Fig. 4 shows one of the banks of valves used in the high-power amplifier of the GBR transmitter, and Fig. 5 shows the variable aerial tuning inductance. It is interesting to compare these with the corresponding units in Fig. 6 which shows a part of the power-amplifying stage of a short-wave transmitter.

Long-Wave Telephone Transmitter.

This transmitter, installed by Standard Telephones & Cables Co., Ltd., to the order of the Post Office, operates on the single-sideband system, wherein the carrier wave and one set of sideband frequencies resulting from speech modulation of the carrier-wave, are suppressed. This is effected by a double process of modulation, whereby the speech-frequencies are first translated to a frequency band of 30-33 kc.p.s. and then modulated by a frequency of 99·5 kc.p.s. By this means, the three products of modulation, i.e., upper sideband, carrier-wave and lower sideband are separated sufficiently to allow the unwanted carrier-wave and the upper sideband to be simply filtered out while the lower sideband, having a mid-band frequency of 68 kc.p.s. corresponding to a wavelength of 4412m, is amplified and passed to the aerial. The net result of this system is that the full maximum power output of the transmitter can be utilised for the transmission of energy in one sideband only, which means that the effective speech energy is transmitted at a level corresponding to 6 db. above that which would be possible if the carrier and both sidebands were radiated. The final amplifier, which was equipped initially to operate with twenty-four

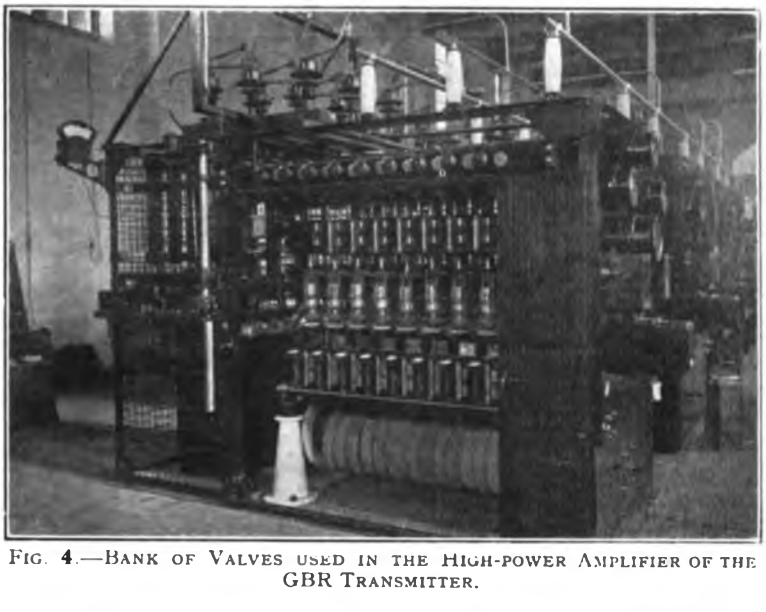

FIG. 4.—BANK OF VALVES USED IN THE HIGH-POWER AMPLIFIER OF THE GBR TRANSMITTER.

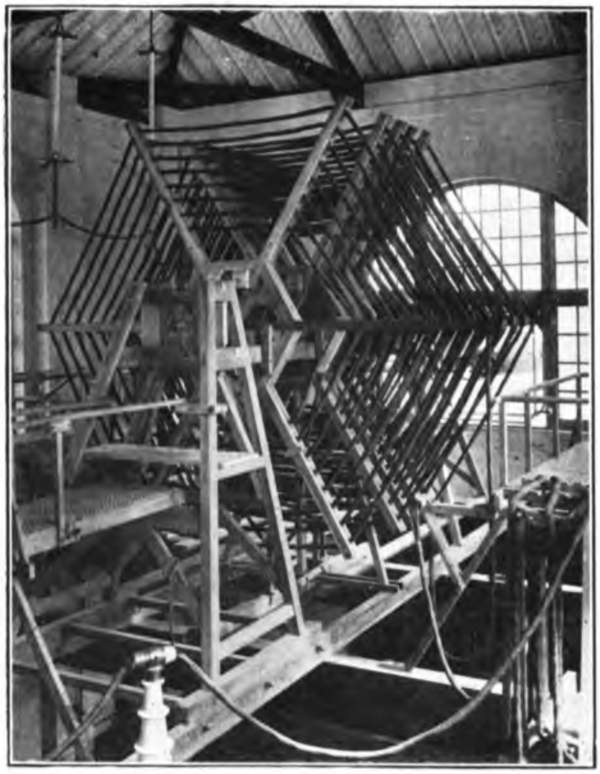

Fig. 5.—Variable Aerial Tuning Inductance.

10 kW valves, is now normally operated with three 100 kW valves, which number can be increased to six if radio conditions warrant the use of increased power. The peak output power of the transmitter is normally of the order of 80 kW. A difficulty associated with the transmission of speech on long wavelengths is that the output circuits and aerial system, if to be efficient and undue expenditure in mast height is to be avoided, are necessarily of low decrement and therefore sharply resonant. Thus it is difficult to secure transmission of all necessary speech frequencies at a sensibly uniform amplitude. Special provision had to be made in the transmitter design to broaden the overall frequency response curve by the use of special couplings between the stages and between the output stage and aerial. The actual frequency-response curve of the long-wave transmitter is shown in Fig. **7.** This response, although wide enough for the transmission of commercial speech without undue loss of intelligibility, is too narrow in terms of a modern good-quality telephone circuit. This, combined with the extreme difficulty in obtaining additional frequency-bands in the long-wave portion of the æther spectrum, and coupled with the relatively high level of static on these wavelengths which, in turn, necessitates the use of an extremely powerful and costly transmitter, were the factors which caused the possible use of short wavelengths for radio-telephone services to be actively investigated.

Short-Wave Transmitters.

Double Sideband Type. Of the short-wave transmitters installed in the station, eight are of the conventional radiated carrier, double-sideband type, whereas the latest two are designed for single sideband operation. Four of the former and the two latter are of Post Office design and construction, the remainder being installed by Messrs. Standard Telephones & Cables Ltd. to Post Office order. A photograph and a schematic layout of one of the double sideband equipments, which are all designed on similar lines, are given in Figs. **8** and **9**. Some transmitters are constructed to operate on four and others on six selected frequencies lying usually between 5 Mc.p.s. and 20 Mc.p.s.—corresponding to wavelengths of 60-15 metres. These frequencies are derived from quartz crystal plates which, mounted in thermostatically heat-controlled ovens, form the grid-cathode resonant circuit of a valve which oscillates at the natural frequency of the quartz plate when the anode circuit is tuned to approximately the same frequency[3]. Normally, the quartz plates, from considerations of mechanical strength, are ground to a natural frequency of transverse vibration of the order of **3** Mc.p.s. and it is therefore necessary to follow the crystal driven oscillators by one or more frequency multiplying stages, these consisting of single screen grid valves, operating as class C amplifiers, but with the plate circuit tuned to double the frequency of the grid A.C. voltage. After the actual carrier-frequency has been generated in this manner, the power is stepped up by three or, in some transmitters, four stages of amplification in cascade. These stages are installed in separate screened cubicles, and neutralised circuits are used to prevent self-oscillation in any stage due to feed-back from anode to grid circuits through the inter-electrode capacitance of the valves.

[3] *I.E.E.J.* August, 1935.

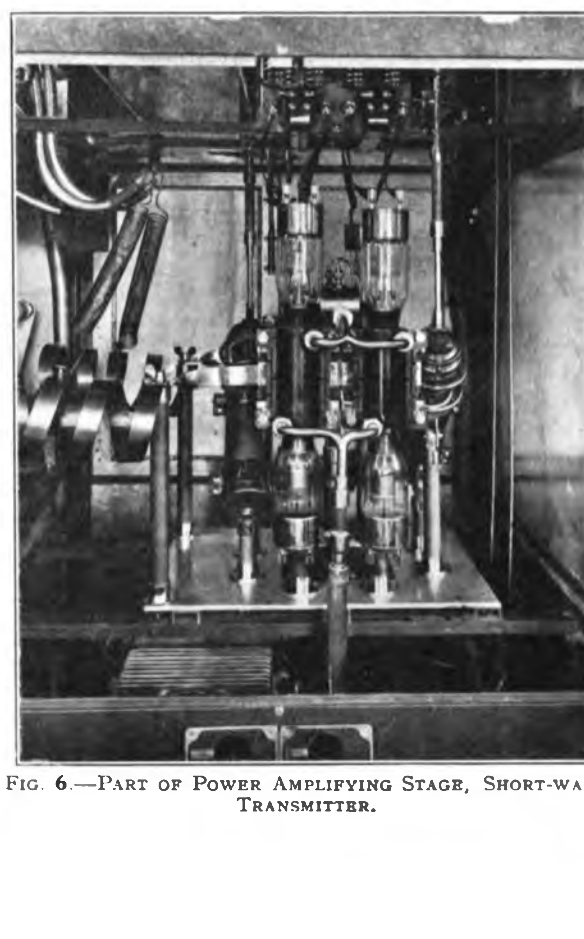

Fig. **6**.—Part of Power Amplifying Stage, Short-Wave Transmitter.

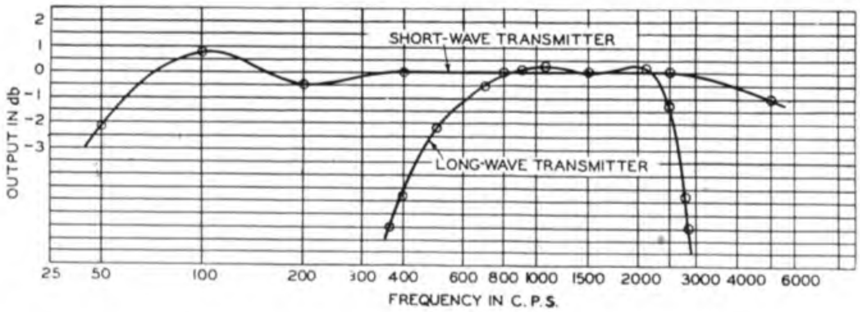

FIG. 7.—AMPLITUDE-FREQUENCY CURVE OF RECTIFIED OUTPUT FROM TELEPHONE TRANSMITTERS.

The modulation is introduced at a point where the high-frequency power level is of the order of 50 watts, using a conventional " Heising " choke coupling. Amplifiers subsequent to this stage, for reasons of efficiency and resulting economy in power consumption, are operated as class B amplifiers. The final amplifying stages are equipped with four 15 kW, water-cooled valves, and are capable of giving, under normal operating conditions, an unmodulated carrier power of 15 kW and a maximum power output, under conditions of peak modulation, of approximately 50 kW. Facilities are provided on each transmitter for checking the carrier power output, the degree of modulation, and the total percentage of harmonic distortion in the output wave form when the carrier wave is modulated by pure sinusoidal tone. The overall frequency-response of a typical transmitter is shown in Fig. 7.

Single Sideband type. The single sideband transmitters, in addition to possessing the fundamental advantage of increasing the effective speech power radiated by concentrating the available power output from the transmitter in sideband energy, are equipped for sending two conversations simultaneously without occupying a wider band of radio-frequencies than is used by a conventional single-channel, double sideband transmitter. To achieve this, three stages of modulation are used, the frequencies at which modulation is effected being governed by the economic considerations of filter design and the necessity of rapidly changing the final radio frequencies to suit diurnal and seasonal conditions. In the latest transmitter, the output from a 100 kc.p.s. crystal-controlled oscillator is modulated by speech from one incoming line in a balanced modulator circuit, and a crystal filter, having a band-width of 6 kc.p.s. is used to separate out the upper sideband of modulation. Speech from the other incoming line is applied to a similar modulator supplied with the same 100 kc.p.s. frequency, but in this case the lower sideband of modulation is filtered out by a crystal-element filter. These two products of modulation, differing in frequency, are combined and utilised to modulate a second crystal-controlled oscillator, having a frequency of 3 Mc.p.s. One sideband of the resulting multiplex modulation is again selected to the exclusion of the carrier-frequency and the remaining sideband, and is used to modulate a third crystal-controlled oscillator, which is tuned to the final radio-frequency $\pm$ 3·1 Mc.p.s. Once again, the carrier-frequency and one sideband is suppressed this time by simple tuned radio-frequency circuits, and the remaining sideband, containing the products of the two incoming conversations, now occupies the correct position in the radio-frequency spectrum. Five stages of amplification, using valves ranging from 75 watt air-cooled pentodes to 60 kW water-cooled demountable tetrodes, amplify the power so that the maximum output delivered to the antenna, under conditions of peak modulation on both channels, is about 70 kW.

In order to facilitate the replacement of the carrier-frequency at the reception point at the correct frequency, a small amount of power on the nominal carrier frequency is radiated. The level used is 15-20 db. below the peak sideband level, and thus only a very small proportion of the available energy is so utilised.

To enable the wavelength of the transmitter to be changed rapidly, the coils in the final radio-frequency stages are mounted on turntables and can be quickly rotated into position by external control.

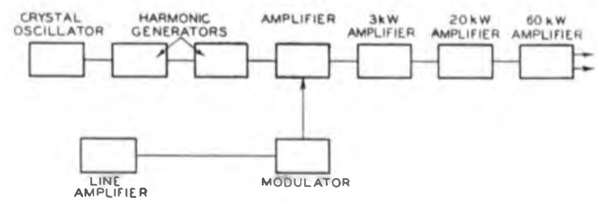

FIG. 8.—SCHEMATIC LAYOUT OF DOUBLE SIDEBAND SHORT-WAVE TRANSMITTER.

Aerial Systems.

Long Wave. The long-wave aerials are suspended from stayed steel masts of lattice construction, which have a height of 820 ft. and are supported on insulating porcelain discs. The aerials are of the " sausage " type, consisting of a number of wires arranged circumferentially at a radius of six feet from a central steel rope which takes the tensile stress due to the weight of the system, and are designed to work without brush discharge at a very high voltage (which for the GBR aerial has a working value in excess of 150,000 V).[4]

Short Wave. The short-wave aerials are nearly all of directional type and are mostly made up of a number of horizontal radiating elements suspended from self-supporting mast systems which vary in height from 120 ft. to 180 ft. A schematic diagram of a typical aerial system is shown in Fig. 10. The radiating curtain consists of 24 horizontal elements which are constructed to be electrically one half-wavelength long at the operating frequency and are spaced one half-wavelength apart in the vertical plane. The curtain is fed from the transmitter by open-wire transmission lines, which consist of two solid copper

[4] *I.C.E.J.* Vol. 221., p. 201.

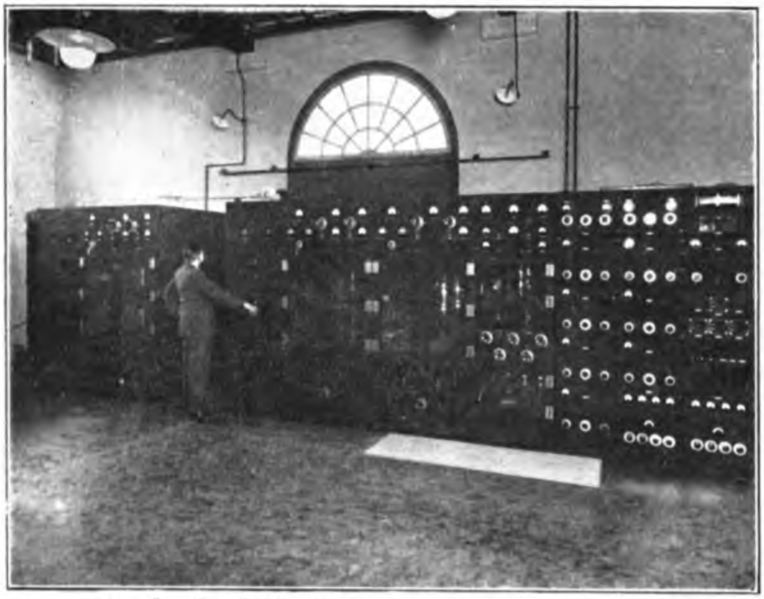

FIG. 9.—DOUBLE SIDEBAND SHORT-WAVE TRANSMITTER.

wires approximately 0·16 in. in diameter mounted 9 in. apart.

The impedance of a pair of half-wavelength radiators is approximately 4,800 ohms but the surge impedance of each of the branches of the feeder system, and that of the main line, is approximately 600 ohms. Accordingly reflections occur at every point where a radiator joins a transmission line and a series of standing waves then exist in the feeder system. When standing waves exist, the impedances at points on the line situated one half-wavelength apart are equal but the currents thereat are of opposite phase. Advantage is taken of these facts to design the feeder system so that not only are the currents in all radiators in the same phase but the impedance of the curtain as a whole, at the point where the main transmission line branches into the subsidiary feeders, is brought down to a value comparable to that of the surge impedance of the transmission line. Thus in the array shown in Fig. **10**, the impedance of the curtain which is effectively that of twelve doublets in parallel is about 400 ohms. In order to secure maximum transfer of energy from, and avoid reflection in, the main line, a transducer consisting of a line one-quarter wavelength long having a surge impedance equal to the geometric mean of the impedances of curtain and main line respectively, is inserted to step up the impedance to 600 ohms at the point of junction with the main line. A curtain, similar to the radiating curtain, but normally energised by induction, is suspended one quarter wavelength behind. The polar diagrams of radiation in the horizontal and vertical planes for the array described are shown in Figs. **11** and **12**. The effective radiation in the desired direction, compared with that of a single half-wave radiating element, is increased by 16 db. corresponding to a power increase of 40 times.

It will be apparent from the foregoing that the aerial is only efficient at the frequency and in the direction for which it is designed to operate, and thus it is necessary to have individual aerials for each wavelength used on each service. Actually no fewer than 43 directional aerials, designed for operation between 12·5 and 70 metres (24,000 kc.p.s.-4,300 kc.p.s.) are installed. It is of interest to note that, in order to economise in mast costs, opportunity is often taken to suspend two aerial systems operating on different wavelengths from the same mast system.

Some of the aerials at Rugby have as many as 64 elements in each curtain and thus have a considerably greater directivity than that described; whereas some others, principally on the longer wavelengths, are rather less directive because of the greater space requirements and resulting increased cost. The polar diagram of radiation in the vertical plane is governed by the number of elements stacked above each other and by the height of the lowest element above the ground and this is adjusted to suit, as far as possible, the propagation path of the service in question.[5] On long-distance services, it is usually desirable to produce as great radiation as possible at low angles, say 8°—12° to the horizontal. On shorter distance services, the main lobe of radiation can profitably be directed at a higher angle, say 12°—20° to the horizontal.

For one or two transmissions it is desirable to be able to radiate either in a forward or backward direction, e.g., the service to Australia, which can be reached by the shorter great circle path in a N.E. direction, or over a longer path in a S.W. direction, dependent on the time of day. This is effected by providing separate transmission lines to feed the radiating and reflecting curtains, and supplying power to either curtain at will. In other transmissions e.g., to provide services to Rio de Janeiro and to Buenos Aires from the same aerial system, it is desirable to slew the radiation through a small angle,

[5] *I.E.E.J.*, June, 1934.

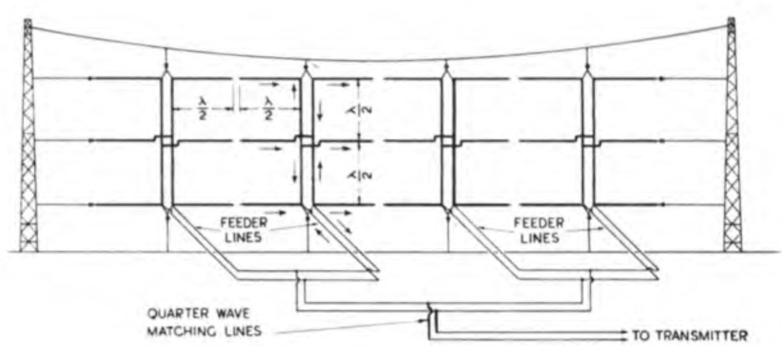

FIG. **10**.—HORIZONTAL SHORT-WAVE AERIAL—RADIATING CURTAIN.

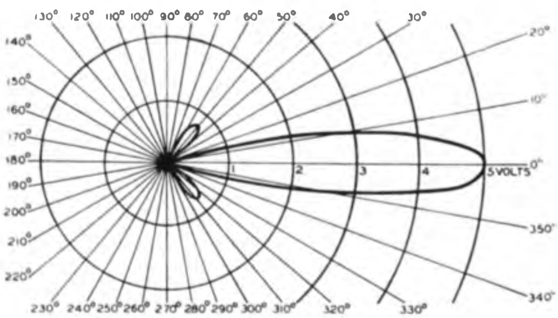

FIG. 11.—POLAR DIAGRAM IN HORIZONTAL PLANE.

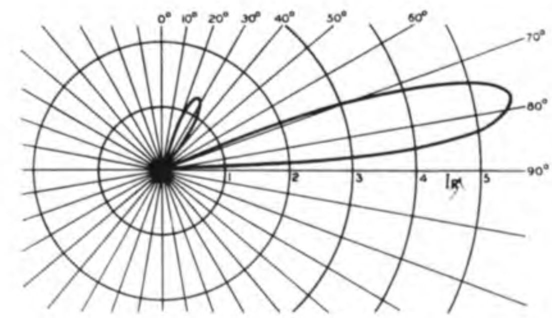

FIG. 12.—POLAR DIAGRAM IN VERTICAL PLANE.

This is effected by providing separate transmission lines to the two halves of the radiating curtain and reversing the phase of the currents in one bay relative to the other.

Open-wire transmission lines are used throughout, the loss at radio frequencies being about 4 db. per mile. Some of the antennæ are necessarily situated at a distance approaching one mile from the transmitter. Arrangements are provided, by a system of transmission lines between the buildings and inside each building, for any transmitter to be able to pick up any array.

Future Developments.

Owing to the fact that short-wave communication, which is effected over long distances by indirect rays which are reflected from the ionosphere, tends to be unreliable when the ionosphere is affected by magnetic disturbances, plans were made for the installation of a second long-wave transmitter for use on the transatlantic telephone service. This transmitter, thanks to the general advance in the radio art since 1927, would have been an improvement over the existing long-wave telephone transmitter, both as regards the effective radiated power and the quality of transmission, and its use would have meant that the busy service to New York would not be too seriously dislocated, even under the worst short-wave propagation conditions. Recent advances in short-wave technique, however, e.g., the use of single-sideband transmission, the increase in output power of transmitters and the reduction in fading by the use of multiple-receiving antennæ, have indicated that it may be possible to reduce the effects of ionosphere disturbances to a degree which will not seriously interrupt traffic operation. Moreover, such methods should provide, during normal conditions, additional channel capacity which could not be achieved by the use of long wavelengths. It is somewhat doubtful, therefore, whether the project to install an additional long-wave transmitter will be carried into force. On the short-wave side, however, it is probable that the future will see demands for considerable expansion in the number of available circuits, owing to the growth in the telephone traffic with other countries. This will involve the problem of obtaining sufficient wavelengths on which to operate these equipments, a difficulty which is already met with since the available allocations in the short-wave bands are already almost fully occupied. Expansion in circuits, therefore, will involve primarily the more efficient use of wavelengths which are already available. This implies, firstly, a more accurate control of the frequency of the transmitters, so that transmitters can be operated on more closely adjacent frequencies; secondly, the use of single sideband working, as by this means the effective frequency band required for transmission of the intelligence can be halved; and thirdly, the use of multiplex working—say two, three or even more speech modulations on a single nominal carrier frequency, which will, in turn, require improved transmitter characteristics if cross-modulation between the speech channels is to be avoided. Developments will also be concentrated on methods whereby the cost of running the transmitters can be reduced, as this is a considerable item in the total cost of operation of a radio-telephone service. One possible method of achieving this, by the use of demountable valves—with low replacement costs—in the high-power stages, has already been indicated. Another method may lie in the use of more efficient directional aerial systems, by which the radiation can be concentrated into narrower "pencils" than at present, thus allowing a reduction in the power output from the transmitters, with corresponding reduction in valve size and power consumption. It is possible, therefore, that future equipments may differ in certain radical features from those at present installed and that some of the existing apparatus may have to be rather drastically modified.

Conclusion.

In a review of this nature, it has not been possible to go into the detailed technical considerations of the design of various equipments. Some references to fuller descriptions have been given, and it is hoped that at future dates more detailed technical descriptions of some of the plant will be published.

A New Short-wave Transatlantic Radio Receiver

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U.D.C. 621.396.62.029.62

A short wave single sideband radio receiver has been built for operation on the transatlantic telephone service. The receiver is designed to receive a transmission which incorporates two independent single sideband speech channels arranged in two frequency bands, one band being above and the other below the frequency of a pilot carrier. The two channels occupy approximately the bandwidth which would normally be occupied by one double sideband transmission.

Introduction.

MORE than fifteen years ago J. R. Carson of the Bell Telephone Laboratories demonstrated mathematically that only one sideband of a speech modulated carrier is necessary for the complete and accurate transmission of intelligence. In fact, certain advantages can be claimed for a single sideband system as opposed to a double sideband system with carrier. In brief these advantages are (1) a saving in frequency range, (2) an improvement in the signal-to-noise ratio obtainable for a given power transmitted and (3) reduced distortion due to wave interference. Radio and carrier engineers were quick to appreciate the advantages of the single sideband technique and the application to long-wave radio circuits and to wire carrier circuits proceeded rapidly. For instance, the long-wave transatlantic telephone circuit[1] commenced commercial operation in 1927 using the frequency band 58·550-61·250 kc/s for a single channel between New York and London, the same frequency band being used for transmission in both directions The transmitted sideband is heterodyned at the receiver with an oscillator of good frequency stability to yield audio frequencies corresponding, within a few cycles per second, to those supplied to the distant transmitter.

The application of single sideband technique to short waves (100 to 12 metres, 3 Mc/s to 25 Mc/s) was, however, delayed for several years in spite of the advantages to be gained by its adoption. The major difficulties lay in the development of a sufficiently high degree of stability in the heterodyning oscillator used in the receiver and in the frequency of the radiated carrier. This long period stability is required to be such that the audio frequency output of the receiver is never in error by more than about 20 c/s for commercial quality speech (250-2,750 c/s) or by more than about 4 c/s if the channel is to be used for music transmission (50-6,000 c/s). The frequency stability required is, therefore, of the order of 1 part in 10^7. This is an extremely stringent requirement but it can be met by a laboratory type crystal-controlled oscillator using a low temperature coefficient quartz crystal plate in conjunction with a precisely temperature-controlled oven.

A more economical solution consists in arranging that one of the heterodyning oscillators of the receiver shall be automatically tuned to follow the frequency of the carrier radiated by the distant transmitter. The stability of the frequencies of the heterodyning oscillator and the transmitted carrier is not critical and simpler and cheaper oscillators may then be used. In order that the sense and amount of frequency correction necessary shall be made known to the automatic tuning apparatus, a pilot carrier is transmitted with the sideband. To economise in transmitted power the pilot carrier may be reduced to a level 16 to 26 db. below the peak sideband level. The pilot carrier after selection and amplification can be utilised for demodulation and also for the operation of the automatic gain control of the receiver. This is the method which has been used in the present receiver and also in various other forms of short wave single sideband receivers operating on commercial radio telephone circuits[2].

Advantages of the Single Sideband System.

For a given peak power output from the transmitter, the single sideband system shows a theoretical signal-to-noise advantage of 9 to 12 db. which is equivalent to raising the transmitted power by from 8 to 16 times, over the double sideband system, assuming that the radio frequency noise components are uniformly distributed over the frequency band occupied by the transmission. Of this improvement, 6 db. is derived from not transmitting the carrier and 3 db. from halving the frequency band occupied, and a further improvement of up to 3 db. may be obtained since, when wave interference occurs, the corresponding components of the sidebands of a double sideband transmission do not retain symmetrical phase relationships with respect to the carrier and so tend to add on a power and not a voltage basis. This signal-to-noise improvement is of considerable advantage in extending the time during which a circuit can be kept in operation during periods of disturbed radio conditions. Alternatively, the transmitted power can be reduced when conditions are favourable, so saving on valve and power costs.

Double sideband short wave radio telephone circuits are subject to deterioration of quality due to the effects of wave interference; single sideband reception with high level carrier at the demodulator, corresponding to a low modulation depth, offers a considerable improvement in quality. Studies of pulse reception over the transatlantic path indicate that signal energy arrives at various down-coming wave angles and is subject to various time delay differences up to 3 milliseconds between signals which have traversed different ether paths. The interference between two or more signals with a time delay difference which is varying, results in the selective fading characteristic of most short wave circuits. Not only does the selective fading result in rapid changes of the apparent audio frequency characteristic of the circuit, but it also produces distortion by giving rise to a condition corresponding approximately to

[1] *P.O.E.E.J.*, Vol. 20, p. 52.

[2] *I.E.E.J.*, Sept., 1934, Proc. I.R.E. July 1935 and Feb., 1938.

over-modulation at the transmitter. This condition arises when the carrier fades below the combined level of the side frequencies. For economy the short wave telephone transmitter is deeply modulated in order to produce the highest possible signal-to-noise ratio at the receiver with a given peak power; the effect is, therefore, quite pronounced and is especially disturbing on a music channel. In single sideband reception it becomes possible to abstract the pilot carrier from the signal by a filter having a bandwidth of 200 c/s or less, to amplify the carrier separately and to insert it into the demodulator of the receiver at a considerably higher level than the peak sideband level, e.g. at about 10 : 1 ratio. In addition, the pilot carrier may be passed through a saturated amplifier so removing modulation and/or transmitter hum and enabling the carrier to be fed to the demodulator at substantially constant level, in spite of carrier fading. Alternatively, a local carrier of suitable frequency may be used. Although it would be possible to abstract the carrier in a double sideband transmission and to supply it to the demodulator at high level, the audio output might be distorted since the phase of the carrier in such a transmission is of considerable importance. Also, it can be shown that, with double sideband transmission, interference between signals with a time delay difference produces a condition of amplitude and phase asymmetry which results in the production of a second harmonic of the modulating frequency[3]. This cause of distortion is absent in single sideband transmission.

The changing audio frequency response characteristic of selective fading is present to about the same extent with single sideband reception as with double sideband reception; it would appear that only a highly selective antenna system, steerable in the vertical plane containing the great circle path between transmitter and receiver, would be effective in reducing these changes.

With a view to confirming the advantages of the single sideband system in an objective manner, tests were commenced late in 1933 and continued in the early part of 1934, between the radio terminal, London and the Bell Telephone Laboratories, New York, these tests including articulation and intelligibility tests. They confirmed the theoretical advantages of the system from the standpoint of signal-to-noise ratio improvement and reduced distortion due to wave interference.

The saving in frequency range offered by the single sideband system is of great importance since it can be obtained in no other way. Providing that adequate carrier frequency stability is obtained, the number of radio telephone channels which can be placed in a given frequency range in the ether is doubled. The demand for frequency allocations continually increases and it is a matter of considerable importance that each frequency range allocated should be used to the best advantage.

It was therefore decided to proceed with an extension of the scheme whereby the speech signals from two independent callers are arranged to be transmitted simultaneously by a common radio transmitter and occupying approximately the same frequency bandwidth as would normally be occupied by one double sideband transmission.

Frequency Spectrum of the System.

The transmitted frequency spectrum is determined by the privacy system adopted. A typical privacy system used is a switched channel device in which one channel (A) occupies the band 250 to 2,750 c/s on one side of the carrier and the second channel (B) occupies the band 2,500 to 5,000 c/s on the other side of the carrier (Fig. 1). Speech in the A channel adjacent

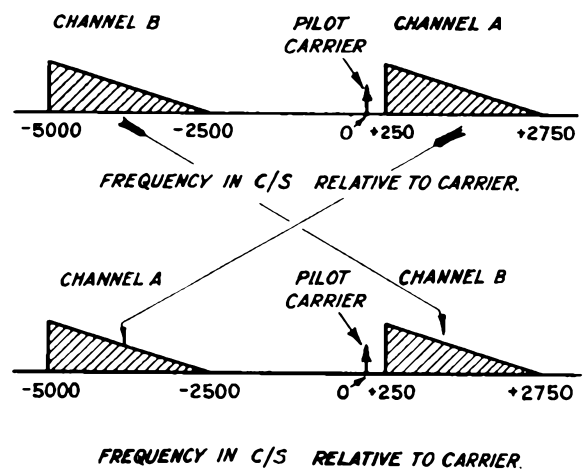


FIG. 1.—FREQUENCY SPECTRA RADIATED BY DUAL CHANNEL SINGLE SIDEBAND TRANSMITTERS.

to the carrier is inverted and the channels are interchanged at short time intervals. This equipment is located at the radio terminals, London and New York.

The spacing of the channels by a frequency band approximately equal to the speech bandwidth reduces crosstalk between the channels to a considerable degree since the intermodulation products of highest amplitude then fall outside the working frequency bands[4]. These intermodulation products arise principally in the final power amplifier stage of the transmitter since this stage has to be fully loaded for efficient working.

The channel filters in the receiver have bandwidths corresponding approximately to a frequency range of 6 kc/s on either side of the pilot carrier, so permitting of various frequency dispositions of the working frequency bands.

Schematic of the Receiver.

The receiver is a triple detection superheterodyne receiver, the block schematic of which is shown in Fig. 2. The first intermediate frequency band is 590-610 kc/s; this relatively high frequency enables an adequate image channel ratio to be obtained with three tuned circuits operating at signal frequency, i.e. two stages of high frequency amplification.

The first beating oscillator of the receiver is controlled in frequency by the control valve and the frequency control equipment so that the carrier at the first intermediate frequency cannot differ from

[3] W. Eng., Oct., 1936.

[4] *Electrical Communications*, Oct., 1937.

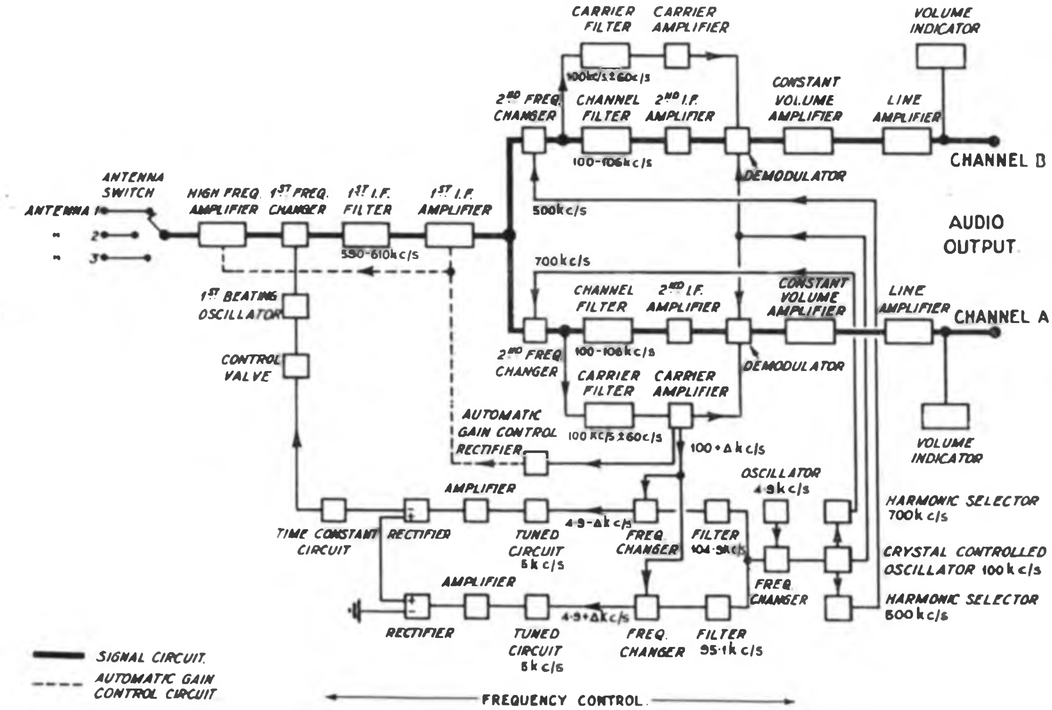


FIG. 2.—BLOCK SCHEMATIC OF DUAL CHANNEL RECEIVER.

600 kc/s by more than a few cycles per second. The first intermediate frequency filter introduces sufficient selectivity in front of the first intermediate frequency amplifier to avoid cross-modulation by strong transmissions on frequency allocations near to the wanted channel. The wanted second intermediate frequency band produced by the second frequency changers is 100-106 kc/s; this relatively low frequency enables channel filters to be designed with suitable attenuation at frequencies corresponding to the adjoining channels combined with a suitable degree of flatness of pass band. In addition, the image frequencies (400 and 800 kc/s) are well removed from the pass range of the first intermediate frequency filter. Two similar channel filters are used for separating the upper and lower sidebands of the transmission by arranging that the second frequency changers are supplied with 500 kc/s feed for one channel and 700 kc/s for the other. These feeds are derived from the 5th and 7th harmonics of the crystal controlled oscillator (100 kc/s). This scheme was adopted for the receiver described, as it has the advantage that only one design of channel filter is necessary. Later single sideband receivers incorporate channel filters having pass bands of 94-100 and 100-106 kc/s.

The pilot carrier is selected from the transmission by the narrow band carrier filter (100 kc/s ± 60 c/s) and passed through two stages of linear amplification in the carrier amplifier. The output of the linear amplifier of the A channel branches to supply a saturated stage, the automatic gain control rectifier, and also a valve which operates a relay in the frequency control unit. The pilot carrier, after passing through the saturated stage, is termed "reconditioned" carrier. The saturated amplifier supplies reconditioned carrier at substantially constant level to the frequency control equipment and to the channel demodulators. A separate carrier selecting circuit is arranged for the B channel in order that the pilot carrier applied to the channel demodulator shall be of correct frequency. Provision is made at the channel demodulator for the use of local carrier derived from the 100 kc/s crystal controlled oscillator, when necessary. Local carrier has been found to yield a slight quality improvement when fading is particularly severe and when the field strength is low. The output of each channel demodulator passes to a constant volume amplifier; a high-pass filter (250 c/s) and a low pass filter (3,000 c/s) are available for use when the displaced band privacy equipment is not in use and it is desired to improve the signal-to-noise ratio by limiting the audio frequency bandwidth. Finally the level is raised to a suitable value (about $+12$ db. relative to 1 mW) for sending to line, by the line amplifier. The audio output level is monitored continuously by volume indicators.

A test oscillator covering the two intermediate frequency bands and fitted with a calibrated attenuator is available for maintenance purposes. A D.C. supply for the heaters of the first beating oscillator and control valve is used to avoid frequency modulation. This supply is obtained from copper oxide rectifiers followed by a suitable smoothing circuit.

Construction of Receiver.

The layout is shown in Fig. 3. Three standard channel-section steel racks, 6 ft. 6 in. high, accommodate the units of the main receiver; the constant volume amplifiers are accommodated on a separate rack not shown in the photograph. Units are mounted on both back and front of the racks in

FRONT VIEW.

REAR VIEW.

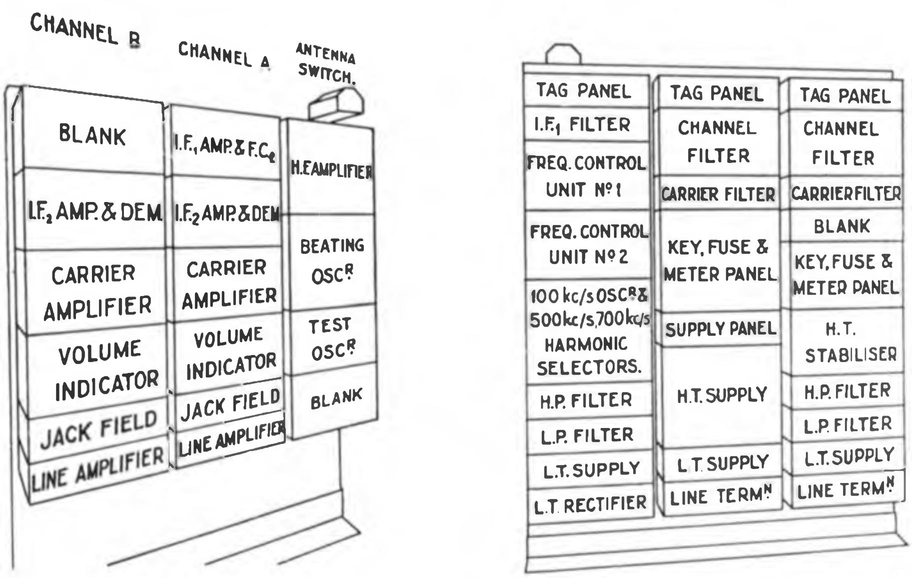


FIG. 3.—LAYOUT OF RECEIVER.

order to economise in space in the receiver building. In most of the units requiring controls mounted on the front panel, a horizontal shelf is incorporated in the unit; valves, transformers and similar components are mounted above and resistors and condensers are mounted below the shelf. Coil switching is arranged in the high frequency amplifier and beating oscillator units so that the frequency range 2·5-25 Mc/s may be covered in three ranges without manual coil changing (Fig. **4**). The construction of the first beating oscillator is especially rigid to avoid microphony and instability of frequency; thermal lagging of the tuned circuit is incorporated in order that any frequency changes due to changes in the ambient temperature shall occur slowly.

Power Supplies.

The power supply to the receiver is obtained entirely from the A.C. supply mains, about 300 watts at 240 volts, 50 c/s, being required. Indirectly heated valves requiring a 4 volt heater supply are used; the power consumption in the heater circuits is 230 watts. The high tension supply of about 320 milliamperes at 200 volts is derived from a full wave rectifier unit using mercury vapour valve rectifiers. The high tension supply to the first beating oscillator and the first frequency changer is required to be extremely stable; this is achieved by the connection of two multi-gap neon stabiliser valves in tandem following a separate high tension rectifier unit.

Frequency Control System.

The first beating oscillator in the receiver is not crystal controlled and is, therefore, subject to variations in frequency due to temperature and heater supply voltage changes. These variations together with those of the transmitted carrier frequency may amount to 8 kc/s at a working frequency of 20 Mc/s; the function of the frequency control system is to ensure that the carrier at the second intermediate frequency will not differ from the frequency of the 100 kc/s crystal controlled oscillator by more than 10 c/s when local carrier is to be used at the demodulator. If reconditioned carrier is to be used, the maximum tolerable frequency error is limited only by the bandwidth of the carrier selecting filter.

In the frequency control unit (Fig. **2**), a 100 kc/s feed from the local oscillator is modulated with 4·9 kc/s and the two side frequencies of 95·1 and 104·9 kc/s are then selected by two bridge crystal filters. These side frequencies are arranged to beat with the reconditioned carrier at a frequency of $100 + \Delta$ kc/s, where Δ is a few c/s, to yield two audio tones of frequency $4{\cdot}9 + \Delta$ and $4{\cdot}9 - \Delta$ kc/s. The audio tones are then applied separately to the sharply resonant tuned circuits L_1C_1, L_2C_2 (Fig. **5**); the tuned circuits have their maximum dynamic resistance at about 5 kc/s. The tuned circuits are identical and therefore are subject to similar changes of resonant frequency due to temperature variations. As the error frequency Δ increases from zero the response of one tuned circuit rises and that of the other falls (Fig. **6a**). The tones are then amplified

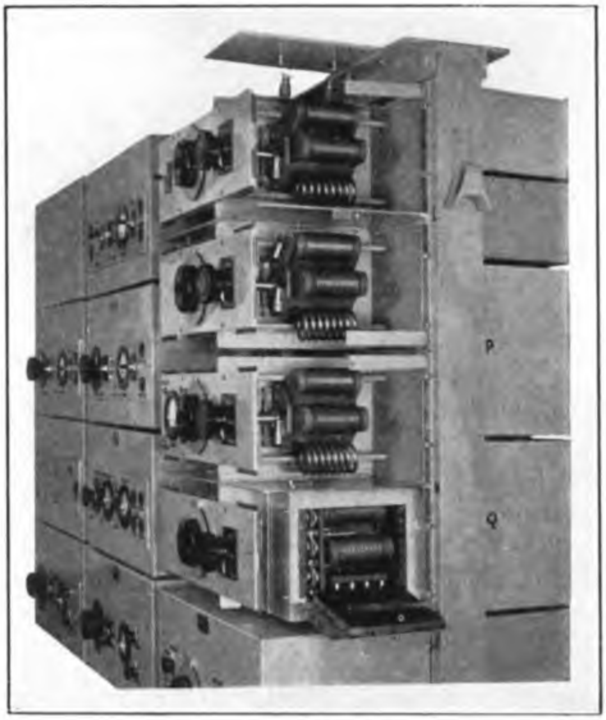


Fig. 4.—Side View of H.F. Amplifier and Beating Oscillator.

and rectified, the output of the rectifiers being connected in series opposition. The difference voltage is applied to a two stage resistance and capacitance filter for smoothing before application to the control valve. The variation in amplitude and sign of the difference voltage as the error frequency passes through zero is shown in Fig. **6b**. Not only is this smoothing necessary in order to prevent unwanted 4·9 kc/s tone from being applied to the control valve but it also serves to prevent transient signals, i.e. static crashes, appearing in the carrier channel from affecting the beating oscillator frequency.

The control valve is a high frequency pentode, the mutual conductance of which may be varied according to the bias applied to the suppressor grid. By the phase shifting circuit RC (Fig. **5**) it can be arranged that the anode impedance of the control valve is substantially that of an inductance $L = RC/m$,

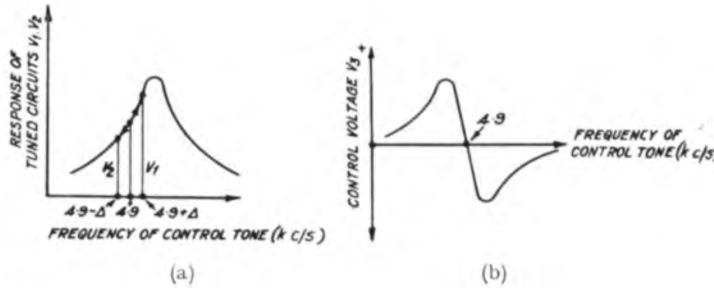


Fig. **6**.—Characteristics of Frequency Control System.

where m is the control valve mutual conductance. This voltage controlled inductance is then used to vary the beating oscillator frequency over a range not exceeding $\pm$ 15 kc/s. During deep carrier fades, or when the transmitted carrier is interrupted, the control circuit is disconnected by the relay contact " a " and the beating oscillator frequency then varies extremely slowly, due to the discharge of the time constant circuit condensers through their leakage resistance. The sensitivity of the control system is about 1000 : 1, i.e. a tendency of the first beating oscillator frequency to change by 5000 c/s from the correct tune frequency results in a final error frequency of about 5 c/s. A key (not shown) is provided so that the sign of the control voltage may be changed as the beating oscillator frequency is changed from a value above to a value below that of the signal. A control is provided so that the system may be balanced, i.e. so that zero error frequency may be made to give rise to zero control voltage. This control requires to be set only infrequently. Also the beat between the local and reconditioned carrier is arranged to be visible as a meter pointer vibration.

The type of control system adopted has the advantage that it operates independently of the drift of the local carrier or control tone oscillators ; in addition, no mechanically variable components are involved and the system may be made to operate independently of carrier amplitude variations over a wide range.

It was found necessary to stabilise the high tension supply to the first beating oscillator and the first frequency changer since sudden changes of the supply voltage were liable to produce a rate of variation of frequency beyond the capabilities of the control system. Variations of frequency due to the heater supply voltage variations are necessarily slow and can be corrected. However, it was necessary to rectify and smooth the heater supply to avoid frequency modulation of the beating oscillator; this effect would become apparent as distortion when the local carrier was in use and degrade the operation of the frequency control system.

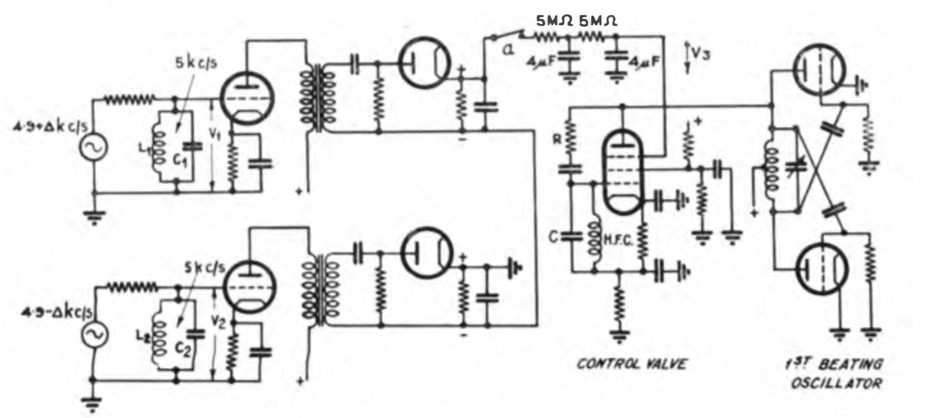


Fig. **5**.—Frequency Control System.

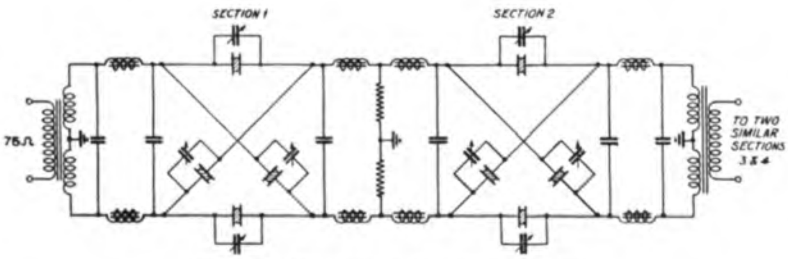
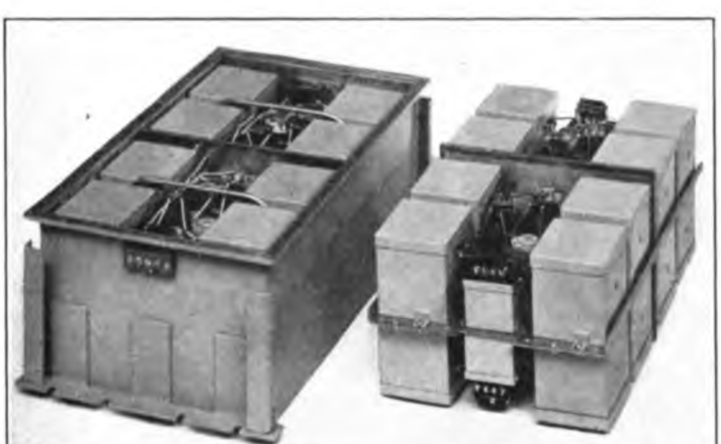


Fig. 7.—Circuit of Channel Filter.

Channel Selecting Filters.

In order that a sufficiently high degree of discrimination against adjacent channel transmissions may be combined with uniform transmission over the frequency range occupied by the wanted channel, the channel filters are of the type using quartz crystal plates as well as condensers and inductors.[5] The filters are similar in principle to those employed in the London-Birmingham coaxial cable system[6] but employ four lattice sections in place of the two used in the coaxial system (Fig. **7**). The lattice section has the advantage that the resistive components of the impedances of the inductors used for broadening the pass band of the filters may be incorporated as the series elements of H attenuator pads at the junction of the lattice sections, so producing uniform transmission in the pass band. The quartz crystal plates are X cut and utilise the Y wave ; gold electrodes are deposited on the plate, which is clamped at two points along the nodal line. The inductors used employ iron dust cores completely enclosing the windings ; the inductance is made variable over a limited range by a screw adjustment of a sliding portion of the core. The power factor is about 0·005. Both the fixed and the variable condensers which tune the quartz crystal plates employ ceramic dielectrics ; the bulk of the capacitance tuning the arms is located in the fixed condensers, which are of low temperature coefficient (40 parts in 10^6 per ^{0}C). The balanced transformers located at the centre of the filter serve to prevent the transmission of currents flowing in phase along the arms of the filter ; these longitudinal currents would otherwise impair the high values of attenuation obtained immediately outside the pass band.

[5] *B.S.T.J.*, July, 1934.
[6] *P.O.E.E.J.*, Vol. 30, p. 272.



Dust Cover and Lid Removed. Assembly Removed from Case.

Fig. 8.—Channel Filter.

The channel filter construction is shown in Fig. **8**. The assembly is sealed in an airtight tinplate case and silica gel is enclosed within the case to absorb any moisture present. The construction provides electrical screening of each section from its neighbours.

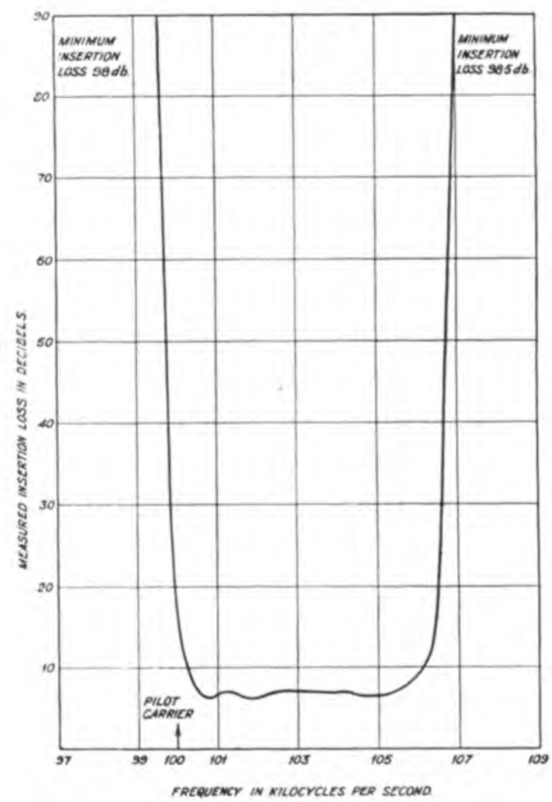


Fig. 9.—Measured Insertion Loss Characteristic of Channel Filter.

The measured insertion-loss/frequency characteristic of a filter of this type is shown in Fig. **9**. The pass band insertion loss is about 7 db., the irregularities in the pass band not exceeding $\pm \frac{1}{2}$ db. relative to the mean response. In order that audio frequencies down to 50 c/s shall be adequately transmitted, some low frequency equalisation is provided in the line amplifier, so making either channel of the receiver available for use in a music channel.

Carrier Selecting Filter.

The carrier filter is a band-pass wave filter incorporating condensers and X cut quartz crystal plates similar to those used in the channel filter, but arranged in the two section ladder circuit shown in Fig. **10**. In order

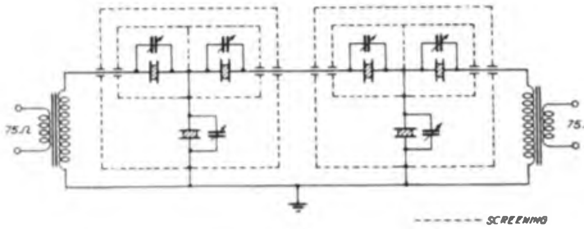


Fig. 10.—Circuit of Carrier Filter.

to localise the capacitances associated with the series arms, double screening is used. Ceramic dielectric variable condensers are used to tune the quartz crystal plates to yield the desired reactance characteristics. The construction is shown in Fig. **11**; the filter is not susceptible to disturbance by a normal degree of humidity in the atmosphere so that sealing is not essential. The measured insertion loss characteristic is shown in Fig. **12**; the effective bandwidth is about 120 c/s.

Automatic Gain Control and the Constant Volume Amplifier.

The automatic gain control circuit is of the delayed type operating from the pilot carrier; the control operates on four amplifier stages in the receiver (two signal frequency and two first intermediate frequency stages). These amplifiers use variable mutual conductance characteristic H.F. pentode valves in which the signal amplitude is kept at a low level in order to keep cross modulation between channels to as low a level as possible. Fig. **13** shows the automatic gain control characteristic as measured with two standard signal generators simulating a single sideband signal.

When selective fading is present on the radio circuit, the level of the receiver pilot carrier is not, in general typical of the level of the side frequencies

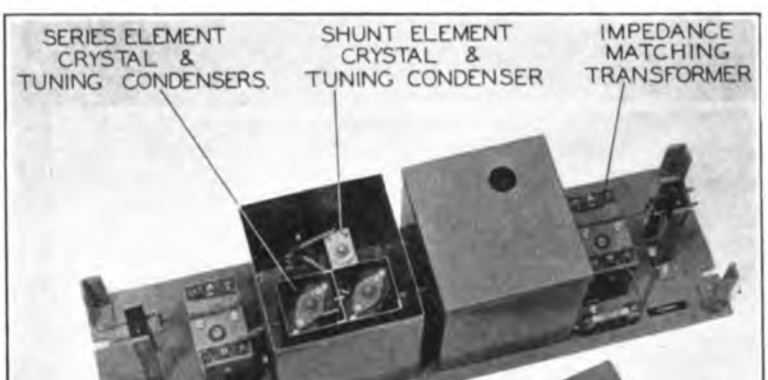


Fig. 11.—Carrier Filter.

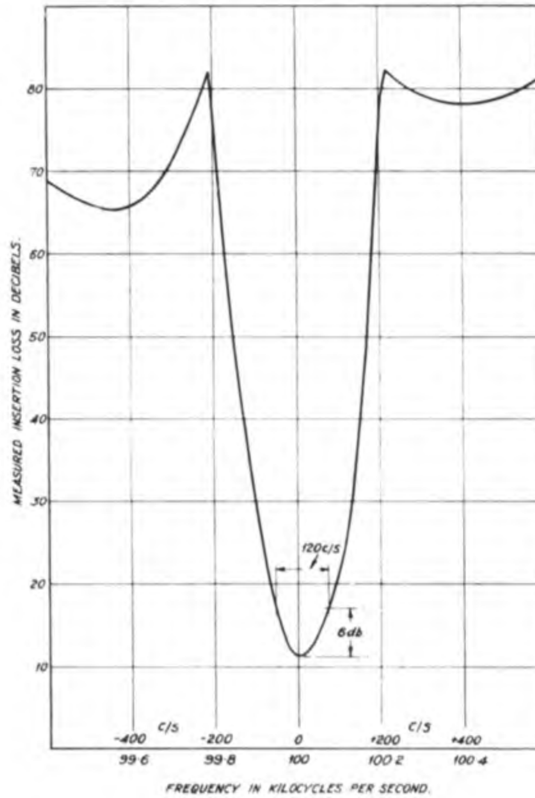


Fig. 12.—Measured Insertion Loss Characteristic of Carrier Filter.

for constant modulation depth at the transmitter. After considerable experimental work involving a wide range of automatic gain control time constants and radio circuit conditions it was decided that an automatic gain control system operating solely from the pilot carrier was not a completely satisfactory means of regulating the audio output level of the receiver. The latter is a matter of considerable importance in connection with the operation of voice operated switching equipment located at the radio terminal, London.

A solution was provided by a constant volume audio amplifier[7] designed to maintain the output level constant to within $\pm$ 2 db. of 1 mW for input level variations of from -15 to $+5$ db. relative to 1 mW. In the idle condition the constant volume amplifier reverts to zero gain, providing that the noise level is below about $-$ 30 db. relative to 1 mW, so that the apparent signal-to-noise level will, on the average, be improved. In a high grade short wave receiver it is important that the inherent noise level in the receiver should be as low as possible. In practice a limit is set by the thermal agitation noise voltage present across the first tuned circuit of the receiver.

[7] *P.O.E.E.J.*, Vol. 31, p. 104.

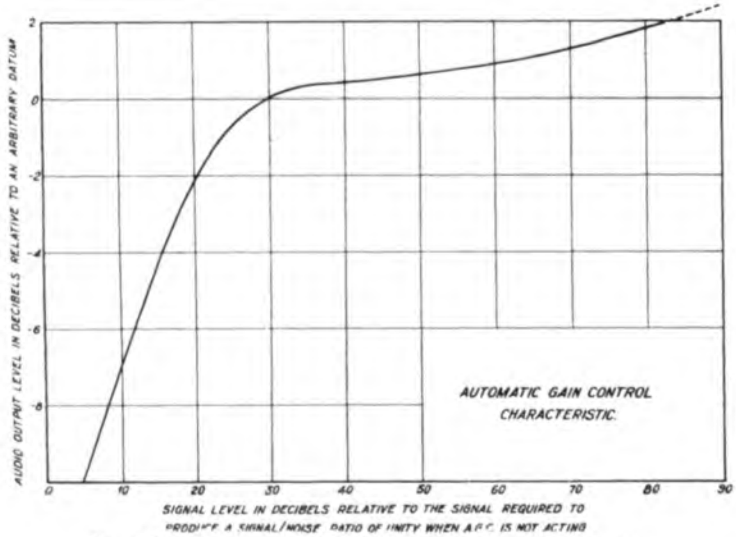


FIG. 13.—AUTOMATIC GAIN CONTROL CHARACTERISTIC.

Performance.

In the present receiver noise due to thermal agitation in the first tuned circuit predominates over all other noise generated in the receiver (mainly anode noise of the first valve) by more than 8 db. for all frequencies below 20 Mc/s.

The ratio of the response at the image frequency to the response at the frequency of the wanted signal is more than 74 db. for all frequencies below 20 Mc/s.

The frequency control system is capable of operating under the lowest field strength condition which will produce a useable circuit. The error frequency (difference between the frequencies of the reconditioned and local carriers) is less than 10 c/s nearly the whole of the time. Little quality difference is apparent, on commercial quality speech, between reception with local and with reconditioned carrier at the demodulator. Carrier fading and static do not upset the operation of the frequency control system.

The channel-to-channel crosstalk ratio due to the receiver alone, measured on tone, is better than 50 db. for the range of input signal levels likely to be encountered in actual operation.

Conclusion.

The receiver was installed in February, 1938, and since that date has been in use almost continuously for traffic circuits and for broadcast speech circuits.

Most of the time the expected signal-to-noise improvement of 9 to 12 db. is realised; this signal-to-noise improvement has proved extremely useful in extending the time period over which the circuit can be maintained when radio conditions are bad. This consideration becomes of increasing importance as 1940, possibly a year of maximum sunspot activity and probably also of maximum disturbance of long distance radio circuits, approaches.

The freedom of the circuit from distortion due to wave interference adds considerably to its value both for normal traffic and for broadcast circuit use.

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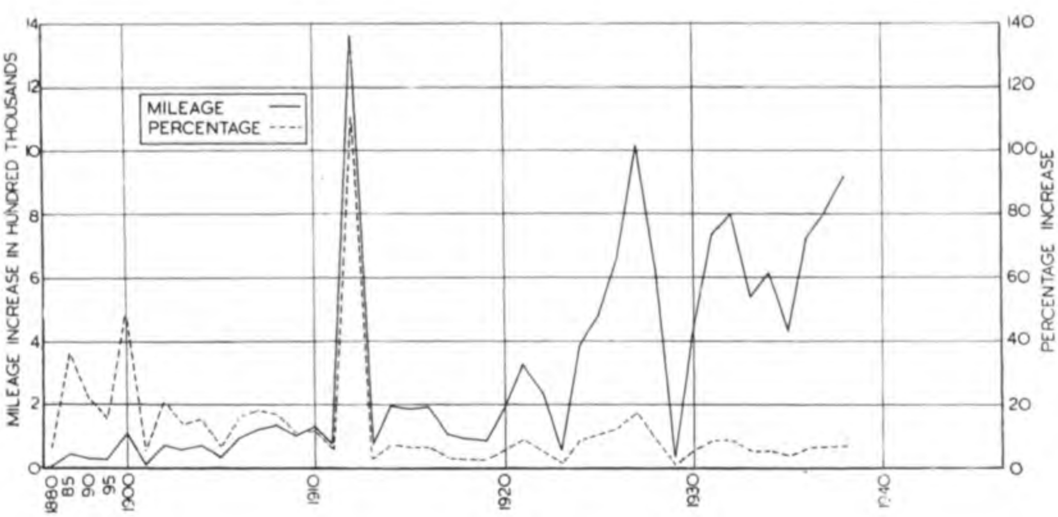

The Reduction of Crosstalk on Trunk Circuits, by the use of the Volume Range Compressor and Expander

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U.D.C. 621.395.648.2 621.395.8

The operation of the compandor is explained and its application to cable circuits for the reduction of crosstalk is described.

Introduction.

THE volume range compressor-expander or "compandor" has been used on radio channels for the improvement of signal-to-noise ratio for some years, but its application to lines is a recent development.

The particular problem in wire transmission for which the compandor offers a solution is that of maintaining secrecy where crosstalk would normally be of such a level as to give rise to intelligible overhearing. The compandor therefore enables circuits such as phantoms and super-phantoms to be put into traffic where previously they would have been unworkable. This enables an increased revenue to be earned by the cable and is particularly useful with sea cables owing to their higher capital cost.

An improvement in signal-to-noise ratio is readily obtainable in a trunk circuit by transmitting the signal to line on the disturbed circuit at an increased power level and correspondingly decreasing the gain of the receiving repeater at the distant end. Such a measure would reduce the crosstalk level, but the repeaters would be seriously overloaded by loud signals, unless their power-handling capacity was increased. The object of the compandor is to raise the level of weak signals transmitted to line without correspondingly raising that of the loud signals. In order to effect this the volume range of the signals in decibels is compressed to a given fraction, say one-half of its normal value. Stated another way, the loud signals pass to line with their level unchanged, but the weak signals receive an amplification inversely proportional to their level; for example, a zero level signal would receive no amplification, but a — 40 db. signal would be amplified by 20 db. and be transmitted to line at a level of — 20 db.

The signal-to-noise ratio is thus considerably improved for the weaker speech sounds, where improvement is most required, without the risk of overloading the transmit repeaters on the loud speech sounds. An improvement in signal-to-noise ratio is unnecessary during loud signals, since these completely mask any interference present, for all reasonable crosstalk levels.

At the receiving end of the circuit the volume range is restored to its original spread by a volume range expander which introduces a loss inversely proportional to input level and equal to the additional gain introduced by the compressor at the transmitting end of the circuit.

The expansion at the receiving end has no effect on the improved signal-to-noise ratio obtained by the action of the compressor, since the additional loss required to reduce the level of a compressed weak signal to its correct value also reduces the crosstalk level by the same amount.

During a silent interval, when there is no signal on the circuit, crosstalk alone will be received by the expander and will be expanded in the same manner as a signal element of the same level, and will therefore be reduced in level accordingly.

The equipment is represented schematically in Fig. 1.

The compressor consists of a speech amplifier, the gain of which is controlled by the output from the control current amplifier-rectifier, the input of which is in turn derived from the output of the variable gain amplifier. The design of the equipment is such that the gain of the speech amplifier is inversely proportional to the signal level across the output terminals.

The expander consists of a loss network having a characteristic which is the exact inverse of that of the compressor speech amplifier. That is to say, for equal signal levels at the output of the compressor and at the input to the expander, the gain in the former and the loss in the latter are equal. The loss in this network is controlled by the output from an amplifier-rectifier identical to that of the compressor.

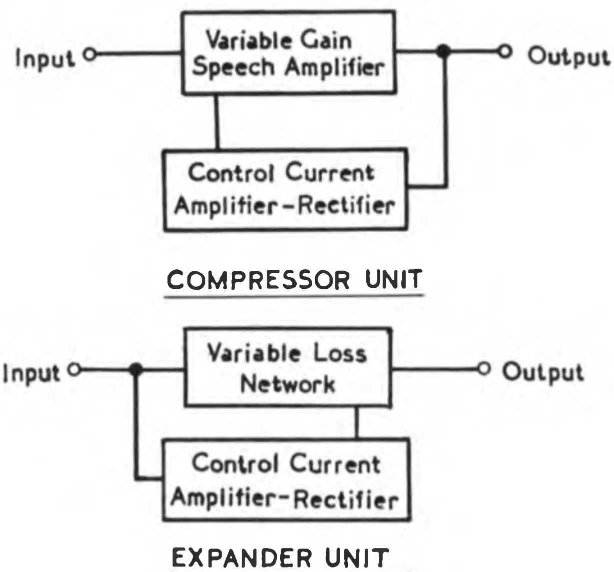

FIG. 1.—SCHEMATIC DIAGRAM OF THE EQUIPMENT.

Choice of Compression Law.

By the term "compression law" is meant the relation between the input and output voltages of the compressor unit.

Whatever shape of law is chosen, that for the expander must be complementary to that of the compressor, in order that the former may correctly restore to its original value the compressed volume range.

Within reasonable limits any shape of compression law is effective, but for ease of specification and matching by the expander a straight line law on logarithmic co-ordinates is usual. That is to say, the compression law is usually of the form $\log V_1/V_2 = k \log v_1/v_2$ where V_1 and V_2 are the output voltages corresponding to input voltages of v_1 and v_2 respectively. If, in this expression, k is unity, the action of a linear amplifier is described, when k is less than unity a volume range compression is indicated and when k is greater than unity an expansion is obtained. If the input power changes by 1 decibel, the output power will always change by k decibels.

A usual value for k is $\frac{1}{2}$ for the compressor, and correspondingly 2 for the expander. (The product of the k values for the two units of the compander must be unity to provide linear operation overall.) The considerations leading to the choice of $\frac{1}{2}$ for the k value of the compressor are that, with this fraction, an adequate reduction of crosstalk is obtained, and at the same time the spurious frequency components introduced by the action of the compressor are not of sufficiently high level to be noticeable.

The compression and expansion laws of the compandor equipment used by the Post Office are illustrated in Fig. 2.

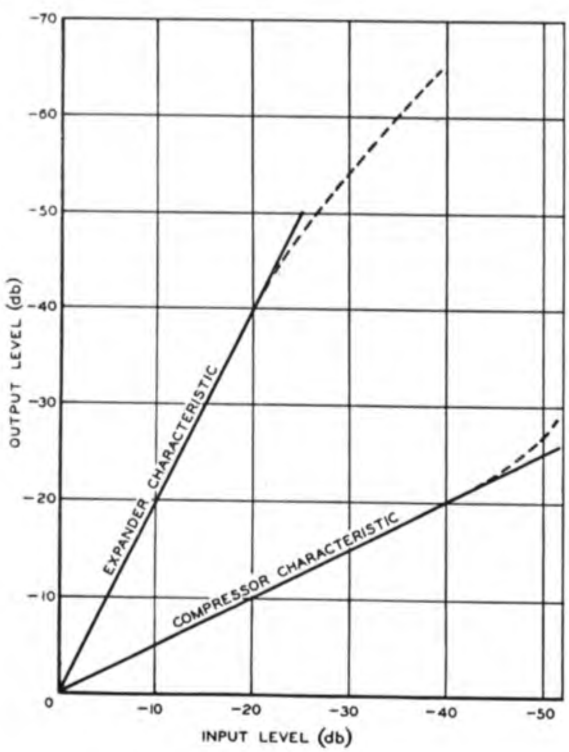

FIG. 2.—COMPRESSION AND EXPANSION LAWS.

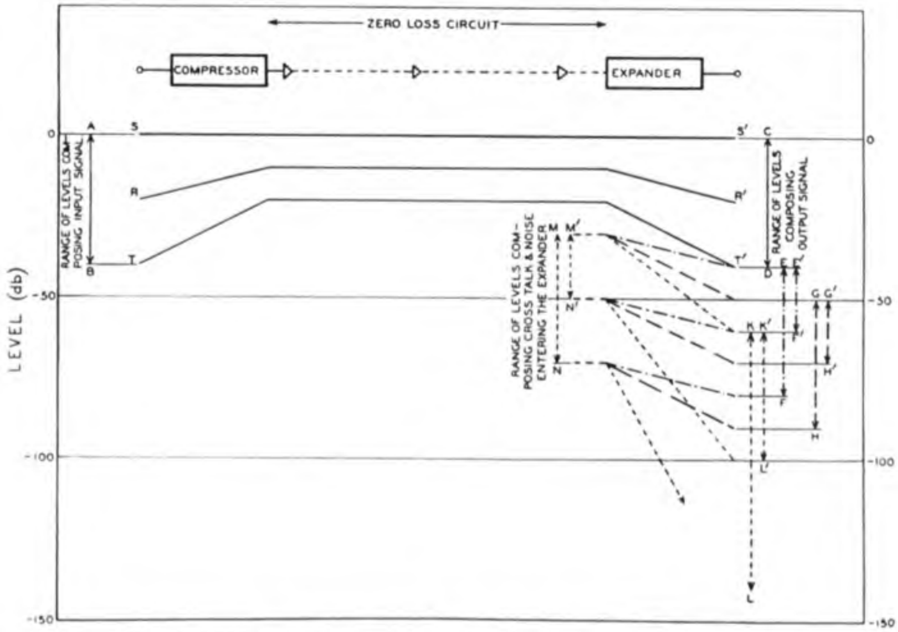

FIG. 3.—LEVEL DIAGRAM OF CIRCUIT FITTED WITH A COMPANDOR.

Action of the Compandor in Reducing Noise and Crosstalk.

Shown diagrammatically in Fig. 3 is a uni-directional circuit fitted with a compandor, together with a level diagram, which illustrates the compression and subsequent expansion of steady tone signals of various levels when each is applied separately.

For the purposes of Fig. 3 ideal compression and expansion laws are assumed, and over a very large range they are taken as being linear. In actual practice, this is, of course, not practicable, the characteristic tending to fall away from the straight line as shown dotted in Fig. 2.

It will be seen from the diagram that one particular level of signal element represented by SS′ passes through the compressor and expander units without change of level. This will be referred to for convenience as "reference level" and should not be confused with "reference volume" or "reference telephonic power" as defined by the C.C.I.F.

Assume that the line AB represents, for the purpose of explanation, the range of levels required for the effective transmission of speech. The compressor reduces this range to one half of AB by virtue of the characteristic of Fig. 2. The lines RR′ and TT′ represent signal elements of levels 20 and 40 db. below reference level which elements will, of course, in speech be of only momentary duration. It will be seen that, from the input of the compressor to the output of the expander, the circuit is linear and weak signals are in no way penalised, with respect to overall transmission equivalent.

MN represents the volume range of an arbitrary level of crosstalk (actually a distant end measured value of 30 db.). When the crosstalk alone is received, i.e. during a silent interval on the circuit, expansion of the crosstalk volume range takes place to KL in accordance with the expander characteristic of Fig. 2.

In addition to the volume range of the crosstalk being doubled, its mean level is considerably reduced to an unintelligible level.

The intelligibility of the crosstalk suffers little from the actual expansion of its volume range and this does not contribute any appreciable part of the reduction in intelligibility, the reduction of which is due solely to the lower level of the crosstalk signals.

The loss introduced by the expander to restore the volume range of the signal elements to its original value is controlled by the total input to the expander, i.e., signal plus crosstalk. The loss in the expander is therefore controlled by the larger of the two components of the total input voltage, except when they are of comparable level. It follows that when a signal element of level RR′ is on the circuit the crosstalk will, after passing through the expander, occupy the range of levels EF, and will receive no expansion, since the crosstalk voltages would be small compared with the accompanying signal voltage. Similarly the crosstalk volume range will occupy the range of levels GH, when in the presence of a signal element of level TT′.

In the particular example illustrated, with no signal on the circuit, the average crosstalk level is reduced by 50 db., owing to the action of the compandor.

The foregoing has assumed that the disturbing circuit is not equipped with a compandor.

Suppose now that the disturbing circuit is thus equipped ; the crosstalk volume range will now no longer be MN but half of this value, although its peak level will remain unchanged. The interference signal will therefore be represented by M′N′ and when there is no speech signal on the disturbed circuit the crosstalk will be received as K′L′ ; with the levels RR′ and TT′ the crosstalk will be received as E′F′ and G′H′ respectively, instead of EF and GH as in the previous case considered. The reduction in the crosstalk level received during a silent interval on the disturbed circuit now becomes 30 db., when compandors are fitted on both the disturbing and disturbed circuits. It can thus be seen that by the use of a compression and expansion device with the characteristics shown in Fig. **2**, the improvement in crosstalk attenuation to be expected under any particular known crosstalk conditions can be estimated from a consideration of the level diagram.

Where speech is of the momentary level SS′ there will be no reduction of the crosstalk at the expander, but this is not necessary as the ratio of speech to crosstalk is high.

Special Conditions to be Satisfied for Successful Operation on a Duplex Circuit.

The principal technical factor which has in the past prevented the use of compandor equipment on trunk circuits where otherwise it would have been justified, has been the difficulty of obtaining an expander unit which accurately restored the compressed volume range and which at the same time was an economical proposition. If the expander law is not an accurate inverse of that of the compressor, instability troubles are encountered on the one hand or weak subscribers are penalised on the other. Fig. **4** shows a 4-wire circuit equipped with compandors. The condition for the compressor and expander laws to be complementary is that the gain in the compressor (C) and the loss in the expander (E) shall be equal for all signal levels. If the equipment is not ideal in this respect and, at some given level, the gain in the compressor exceeds the loss in the expander by an appreciable amount, the circuit will tend to sing, the level of the oscillation building up until a level is reached at which the difference between the gain and loss disappears. If the discrepancy is in the other direction and the loss in the expander exceeds the gain in the compressor, the transmission equivalent of the circuit will be increased.

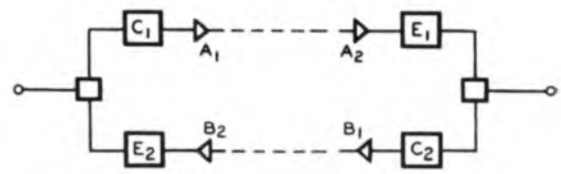

FIG. 4.—4-WIRE CIRCUIT FITTED WITH COMPANDORS.

Since the circuit would be lined up with a relatively high level signal (1 milliwatt), these shortcomings of the equipment would manifest themselves at the lower levels and the increase of overall loss would thus penalise the weak level subscriber. Failure of the expander to restore accurately the volume range is less important with radio circuits, since these are effectively stabilised by the anti-singing device and all incoming subscribers' speech levels are manually controlled to a given value. On trunk circuits, however, an accurate expander is an important requirement for successful operation.

The second requirement is good equalisation of the circuit between the compressor and the expander. Reference to Fig. **2** shows that changes of input level to the expander are doubled at its output and consequently if, prior to the installation of the compandor, the circuit was equalised to within 1 db. of the 800 c.p.s. loss, the maximum deviation will become 2 db. after the compandor is fitted. If therefore, the equalisation of the circuit is to be within the prescribed limits, the equalisation of the section between the compressor and expander must be twice as good as the overall requirements. For the same reason variations of circuit attenuation tend to be emphasised, a variation of 0·5 db. appearing as 1 db.

Advantages and Disadvantages of Transmitted Control Current.

The foregoing discussion has referred exclusively to the system shown in Fig. **1**, which has recently been tried out by the Post Office.

Another system, which has not so far been used in practice, varies from the arrangement of Fig. **1** in that the control current from the compressor control amplifier is transmitted over the circuit to the expander loss network, and no control amplifier at the expander end is required. The advantages of this system are principally :

(1) Greater reduction of crosstalk level in silent intervals on the circuit.
(2) Better restoration of signal volume range when the low level elements of the signal are comparable in level with crosstalk elements.

and the principal disadvantage is :

A somewhat greater complication in routing and maintenance of circuits since the control current must be transmitted.

The reason for the increased reduction of crosstalk in the silent intervals is that the crosstalk, which is injected into the circuit after the compressor, cannot operate the control amplifier. The loss in the expander consequently remains at the high value corresponding to no signal input, no matter what level of crosstalk is received. Since the crosstalk has no influence on the operation of the control amplifier, better restoration of volume range will be obtained where the low level elements of the signal and the higher level elements of the crosstalk are of comparable level.

Although at first sight, the elimination of the control amplifier at the expander would appear to be a simplification, this may be more than offset by the complications involved in transmitting the control current over the circuit.

It should be remembered that the control current is a modulated direct current, which would have important components within the frequency range between zero and the lowest frequency used for the transmission of speech. The repeaters are, of course, unable to handle the very low frequency components of this control current, which therefore would have to be by-passed round each repeater. It is possible that to do this satisfactorily, conjugate high and low-pass filters would be required at each repeater.

It would also be necessary to ensure that the transmission times of the components of the control current and of the signal would not differ by an excessive amount, and with slow-speed circuits a certain amount of phase equalisation might have to be employed.

An alternative method to the transmission of the actual control current would be to transmit a replica of it above the speech frequency band, by modulating a suitable carrier frequency.

The second of these methods is unlikely to find any application in the Post Office, but the former method may be found justifiable in certain circumstances.

The Relative Positions on the Compressor Volume Range Characteristic of Speech of a given level, and of a Milliwatt of Steady Tone.

The effective range of instantaneous power levels concerned in the transmission of speech is of the order of 40 db. This, of course, is independent of the level of the speech, relative to Reference Telephonic Power (R.T.P.).

Assuming speech of a given level relative to R.T.P. it is necessary to be able to design the compressor so that the reference level will be in a predetermined position with respect to the range of levels occupied by the applied speech.

The reference level can, however, only be designed for, or actually directly measured, in terms of steady state signals (e.g. a sinusoidal tone), since on transient signals (of which speech is entirely composed) the operating time of the compressor is involved.

For instance, suppose a steady tone of − 10 db. relative to reference level is applied to the compressor and is then suddenly decreased in level to − 20 db. Provided the decrease in level is maintained for a sufficient time to allow the compressor to operate fully, the output level will change from − 5 db. to − 10 db. Now suppose that the input level is suddenly reduced by 10 db. for a short time only, after which it is restored to its original value. There will not be time for the compressor to reach a new steady state condition, and consequently the average output level during the interval in which the input level is reduced, will decrease by more than 5 db. and will approach the full 10 db. as the time interval is progressively shortened.

It will therefore be seen that the compression law of 2 : 1 for steady state signals will approach 1 : 1 for those portions of the signal consisting of very rapid changes in level.

A practical test is therefore required to determine what steady state power level is equivalent in its action upon the compressor to speech elements in a given position in the speech volume range.

Suppose it were desired to compress the speech volume range about, say, its mean level point. In order that a compressor may be designed to achieve this it is necessary to know at what steady state power input the gain of the compressor is to be zero, i.e., it is necessary to know the reference level.

A method which can be used to evaluate, with sufficient accuracy, the reference level required, follows, and in this connection, consideration is confined to speech transmitted and received on commercial type instruments. It is found that speech remains quite intelligible after compression of its volume range, and its average volume can readily be compared by ear with that of the normal speech.

The assumption is made that, if the mean levels in the volume ranges of compressed and normal speech are equal the two speech signals will appear equally loud to the ear. The actual test consists in applying speech of a known level relative to R.T.P., to the input of a compressor unit which has a reference level of, say, one milliwatt. The output from the compressor is connected to an attenuator, which is

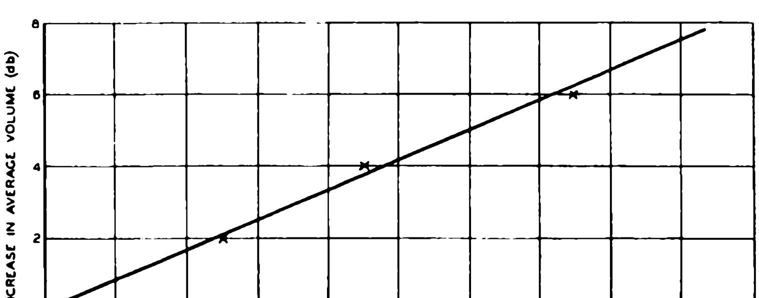

Fig. 5.—Relation between Input Level and Increase in Average Volume.

then adjusted until the compressed speech is apparently of the same level as the normal speech applied to the input of the compressor. If the input speech level is plotted against the loss in the attenuator, which is a measure of the increase in average volume, a straight line is obtained as shown in Fig. **5**, provided the compression law is linear, though the slope of this line will not necessarily be the same as that of the steady state compression law, owing to the effect of the operating time.

The graph of Fig. **5** shows that with an input level of approximately R.T.P., the apparent volumes of the normal and compressed speech are equal. Making the assumption stated above this is interpreted as indicating that the mean level of the speech elements composing the R.T.P. speech is equal to the reference level, and these elements receive neither gain nor loss on passing through the compressor. The volume range of R.T.P. speech is therefore symmetrically distributed on either side of the reference level. Therefore, assuming a 40 db. range of levels for the speech components, the whole of the effective volume range would occupy the 40 decibels below reference level when a speech input of 20 db. below R.T.P. was applied to the compressor. If this condition were required with a speech input of 10 db. below R.T.P. then it would be necessary to design the compressor with a reference level of 10 db. above that of the unit giving the curve of Fig. **5**, but it must have the same operating time characteristics.

By the use of data obtained in the above manner it is possible to design the compressor to have a reference level suitable to the speech level to be handled.

Choice of the Reference Level

All Circuits in the Cable Equipped With Compandors.

The term reference level has previously been applied to the compressor and expander units alone, and is that steady state input level for which the gains of these units are zero. If the compressor unit is followed by an amplifier with a given gain, the reference level of the compressor and amplifier considered as a single unit is raised by twice the amplifier gain. If a loss equal to this gain precedes the expander unit, in order to maintain the previous transmission loss of the circuit, the reference level of the expander is also raised by twice the amount of this loss. In practice, of course, this loss would be a reduction in gain of the receiving repeater.

The reference level of the compressor and expander units can therefore be chosen to be equal to the relative level of the points at which they are inserted in circuit, and by means of the repeaters, the effective reference level is chosen to be that which would give the best all-round reduction in crosstalk.

With this arrangement, the gains of the compandor units are zero when a milliwatt tone is applied to the line input as is done for transmission testing. This is convenient from the maintenance aspect, and the equipment can easily be switched out of circuit while the latter is being lined up, thereby simplifying this process.

When all circuits in the cable are equipped with compandors, the output levels of the transmitting repeaters, as in normal practice, should be equal for all the circuits. The actual level transmitted to line, however, will not affect the crosstalk attenuation, which in a silent interval will be twice that of the circuit without the compandor.

This can be demonstrated as follows :

Let p db. be the power ratio by which the reference level of the system exceeds the mean level in the volume range occupied by speech at R.T.P., i.e. if p is zero the input and output speech levels of the compressor will appear equally loud to the ear when R.T.P. speech is applied.

The severest possible case will be assumed where the law of the compressor remains 2 : 1 with infinitely rapid variations in signal level. This means that with speech x db. below R.T.P. applied to the compressor, the output from the compressor will be $x - \frac{1}{2}(p + x) = \frac{1}{2}(x - p)$ db. below R.T.P. In the practical case illustrated in Fig. **5** the increase in volume is not as great as this, being only $0{\cdot}4\ (p + x)$ instead of $\frac{1}{2}(p + x)$. Let y be the crosstalk attenuation of the circuit (assumed of zero transmission equivalent) before the compandor is fitted. Then the crosstalk level received by the expander will be $\frac{1}{2}(x-p) + y$ db. relative to R.T.P. and the mean level in the volume range of this speech will be $\frac{1}{2}(x-p) + y + p$ db. below reference level.

The crosstalk level at the output of the expander will therefore be $2\ (\frac{1}{2}(x+p) + y)$ db. relative to reference level and therefore $2(\frac{1}{2}(x+p) + y) - p$ relative to R.T.P. i.e., $(x+2y)$.

Without the compandor the received crosstalk level would have been $x + y$ and the effective crosstalk attenuation is therefore doubled by the compandor.

Some Circuits only, in the Cable, equipped with Compandors.

Unless precautions are taken, the compandor equipped circuits will show an improvement in crosstalk, but the non-equipped circuits will be made worse since the average level to line on the equipped circuits will be increased due to the action of the compressors. In order to divide the benefit given by the compandors, between the circuits of both groups, it will be necessary to reduce the output levels of the transmit repeaters of the compandor-equipped circuits, or in other words to reduce the effective reference levels of the compandors.

This is necessary, firstly, to compensate for the increased average speech level resulting from the compression of the volume range, and secondly to improve the crosstalk from the compandor-equipped to the non-equipped circuits.

It should be observed, however, that if by fitting compandors to all the circuits, the crosstalk level could be reduced by x db., then if only one group of circuits is so equipped and the improvement is equally divided between the equipped and non-equipped groups, the maximum reduction of crosstalk level on each circuit will not be $\frac{1}{2}x$ but only $\frac{1}{3}x$.

This can be shown as follows, the symbols having the same meaning as previously :—

With no compandors the crosstalk level between any two circuits will be $x + y$ db. below R.T.P.

Now consider the crosstalk from a non-equipped to a compandor-equipped circuit. The level of the crosstalk entering the expander will be $x + y$ db. below R.T.P. or $x + y + p$ db. below reference level. The level of the crosstalk at the output of the expander will therefore be $2\,(x + y + p)$ db. below reference level, or $2\,(x + y + p) - p$ below R.T.P.

The reduction in crosstalk level from the non-equipped to the equipped circuit is therefore $(x + y + p)$ db., due to fitting the compandor.

Now consider crosstalk from a compandor-equipped to a non-equipped circuit.

On the disturbing circuit :—
the input level to the compressor will be x db. below R.T.P. or $x + p$ db. below reference level. The output level from the compressor will be $\frac{1}{2}(x + p)$ db. below reference level or $\frac{1}{2}(x + p) - p = \frac{1}{2}(x - p)$ db. below R.T.P.

A crosstalk level will therefore be received on the disturbed circuit of :—

$$\tfrac{1}{2}(x - p) + y \text{ db. below R.T.P.}$$

Without the compandor this level would have been $(x + y)$, hence the improvement is :—

$$\tfrac{1}{2}(x - p) + y - (x + y) = -\tfrac{1}{2}(x + p)$$

The improvements in crosstalk from equipped to non-equipped circuits and vice-versa must be equal hence :—

$$(x + y + p) = -\tfrac{1}{2}(x + p)$$

i.e. $p = -\frac{2}{3}(\frac{3}{2}x + y)$ and inserting this value of p in $(x + y + p)$ gives the improvement in crosstalk of $\frac{1}{3}y$.

It was previously shown that when both circuits were equipped with compandors the improvement in crosstalk obtained was y.

Choice of Operating Times.

The operating time of the compandor is expressed as the time taken for the gain (or loss) of the compressor (or expander) to change by 80 per cent. of the value of the final change, on sudden alteration of the input level.

The operating times of the compressor and expander units should be equal and must be long compared with the period of the lowest frequency to be transmitted, otherwise the control amplifier will tend to follow the shape of the actual wave instead of its envelope.

The upper limits to the operating time are set principally by the ear, which it has been shown cannot detect the effects of operating times as long as 70 milliseconds for increasing levels and 100 to 300 milliseconds for decreasing levels.[1]

With the compressor, however, it is an advantage to have a fairly short operating time when the input is increasing, since this minimises momentary overloading of amplifiers.

For trunk circuit use operating times of about 15 to 20 milliseconds have been found satisfactory, and with these the distortion introduced into speech by the compandor has been found not to be at all obtrusive even when tested by trained observers with a high quality microphone and loudspeaker. Further tests to determine the most suitable operating times for compandors on trunk circuits are being carried out.

Oscillograms showing the operation of the compressor and expander units on steady tone, of which the level was suddenly changed, are shown in Fig. **6**.

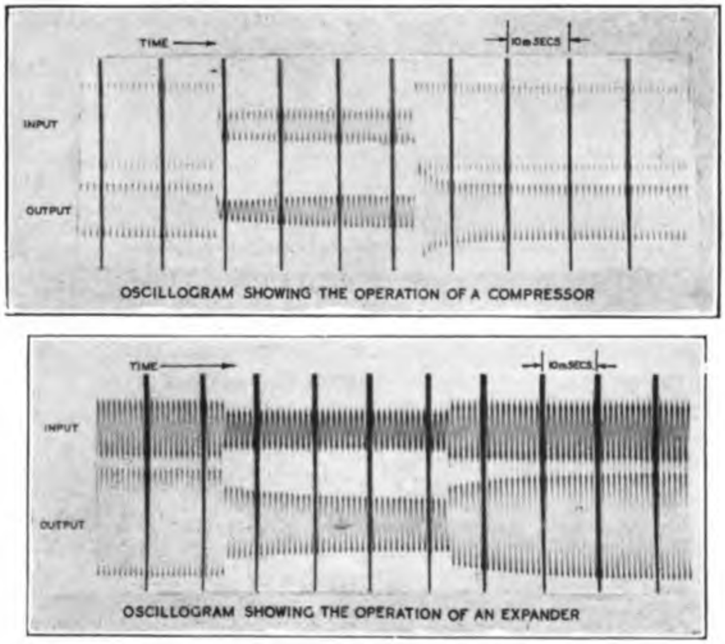

FIG. **6**.—OSCILLOGRAMS SHOWING OPERATION OF THE COMPRESSOR AND EXPANDER.

Effect of the Compandor on Echo Suppressor Operation.

Although the increased average speech level, due to the amplification of the weak elements by the compressor, existing between the compressor and expander, ensures better operation of the echo suppressor, it is, in general, better to locate the suppressor at the terminal outside the part of the circuit in which the volume range is compressed, owing to the increased danger of noise operation.

Results of Trials in the Field.

A compandor equipment was recently given a short trial on a London-Aldeburgh circuit, and is now in service on a London-Rotterdam circuit which is routed on a super-phantom in the Anglo-Dutch No. 3 cable. The crosstalk attenuations in this submarine cable are exceedingly low and the circuit was previously quite unworkable. Since fitting the compandor, however, the crosstalk has been improved to a satisfactory level and is quite unintelligible even during silent intervals.

On the London-Aldeburgh circuit tests were made to determine the actual improvement in crosstalk obtained. The following table gives the result of the tests with artificially produced crosstalk :

[1] *Phil. Tech. Rev.*, July 1938, p. 204

Crosstalk level relative to R.T.P. at a — 5 db. point without compandor db.	Improvement obtained by use of the Compandor db.
— 37	25
— 33	23

Size of Equipment.

The equipment as finally developed is of quite small size, the compressor and expander units being mounted each on one side of a 5¼-in. by 19-in. panel, and therefore make no very serious demands on the available rack space in the terminal repeater stations.

A description of this equipment will, it is hoped, form the subject of a future article.

Conclusion.

The compandor equipment has proved itself to be a very useful device for the reduction of crosstalk on circuits where this is sufficiently serious to endanger secrecy. This occurs particularly on 2-wire (submarine) links, in which there is near-end crosstalk. Since this type of crosstalk cannot be balanced, a compandor is the only practicable means of increasing the effective crosstalk attenuation.

Again, the high capital cost of submarine cables makes it very desirable that full use should be made of their capacity and derived circuits previously unsatisfactory, due to crosstalk, can be put into service by the use of the compandor, the cost of which can usually be very easily justified on economic grounds.

There are other applications which are likely to be important in the near future owing to the increasingly high frequencies which are coming into use for carrier systems due to the employment of group modulation. The limit to the number of channels per pair which can be worked on land cables of the normal type is the crosstalk attenuation at high frequencies. Where the working of 24 or 36 channels is being attempted on cables laid for 12 channels it may be found desirable to equip the top few channels with compandors in order to maintain a satisfactory standard of crosstalk.

A similar problem is met with on coaxial submarine cables with a solid dielectric where the limit to the number of channels is set by resistance and valve noise. The high repeater gains required at the upper end of the frequency band, bring the noise on the top channels up to a level which makes very desirable the use of compandors on these channels to maintain a quiet background.

There are several variations of the above applications of the compandor, and it would appear that this device may in the future have a widening field of application to transmission line work.

Book Reviews

" Handbook of Technical Instruction for Wireless Telegraphists." H. M. Dowsett. 624 pp. 578 ill. Iliffe. 21s.

This work has now reached its sixth edition, having first been published in 1913 under the authorship of Mr. J. C. Hawkhead and revised in 1915 and at intervals since by the present author. Its aim is to provide simple instruction for sea-going operators and others in the general principles and practice of marine wireless communication, illustrated by descriptions of apparatus developed by British wireless companies, nearly all the apparatus described being in actual use afloat. This makes the book of particular use to operators, who may be faced with the maintenance of such equipment over a period of many years although it is obvious that the present rapid progress in design is liable to render the descriptions of little interest to other members.

Some 180 pages are devoted to a discussion of general electrical principles and apparatus, including chapters on the condenser, scalar and vector quantities, primary batteries, accumulators, diagrams, alternating current effects and fundamental formulae, alternating current generators, motors and transformers before dealing with the wireless equipment proper. This last section contains chapters on transmitters, receivers, depth sounding devices, wavemeters, marine direction finders and marine audio relay services. In view of the importance of wireless wave propagation to the successful working of marine operators, more pages dealing with this phase of the art would undoubtedly have enhanced the value of this handbook. A. H. M

" Fractional Horse-Power Electric Motors." C. G. Veninott, B.S., E.E. 431 pp. 315 ill. McGraw-Hill. 21s.

This book is primarily intended to serve the needs of practical men engaged in installation, maintenance or repair of fractional horse power motors. The N.E.M.A.'s (Amercan National Electrical Manufacturers' Association) definition of a " fractional horse-power motor " is one built in a frame smaller than that having a continuous rating of 1 h.p. open type at 1,700 to 1,800 r.p.m. and thus differs somewhat from the British definition.

A comprehensive table, giving type letter designations of motor of American manufacture, with which the book deals exclusively, is given in the first chapter. Elementary theory of A.C. and D.C. machines is briefly dealt with and serves as an introduction to constructional details. As is to be expected from the variety of A.C. motors available and the relative number of A.C. and D.C. motors in use, 14 chapters are devoted to the former as against one chapter each for Universal and D.C. motors.

The descriptive matter, amplified as it is by over 300 illustrations and wiring diagrams, should be readily understood by those with limited technical knowledge, and fulfils the intention of the author in giving practical men essential information in dealing with maintenance and repair problems, including rewinding, changing speed, altering direction of rotation, etc. A useful chapter on testing and a trouble diagnosis chart are included. W. T. G.

The Post Office Work in Conjunction with the Finchley Road and Swiss Cottage Metropolitan Railway Improvements

H. E. MORRISH and
W. P. CHASMAR

U.D.C. 621.395.74 621.315.23 625 624.19

In view of the increasing number of major road works and alterations involving the Post Office plant it is thought the method adopted in a recent case in London will be of general interest. The case is treated more from the planning and co-ordinating aspect than from the actual works operations, the latter being of standard application and well known. The importance of close working with other statutory authorities and undertakers and the preparation of operation orders and time tables is indicated.

Introduction.

IN 1935 the London Passenger Transport Board obtained Parliamentary powers for the extension of the Bakerloo Tube from Baker Street. The design was to duplicate the up and down tracks which exist on the Metropolitan line between Baker Street and Finchley Road stations, and also to secure through-running between the Bakerloo underground system and the whole net-work of the Metropolitan lines in the north-west suburbs.

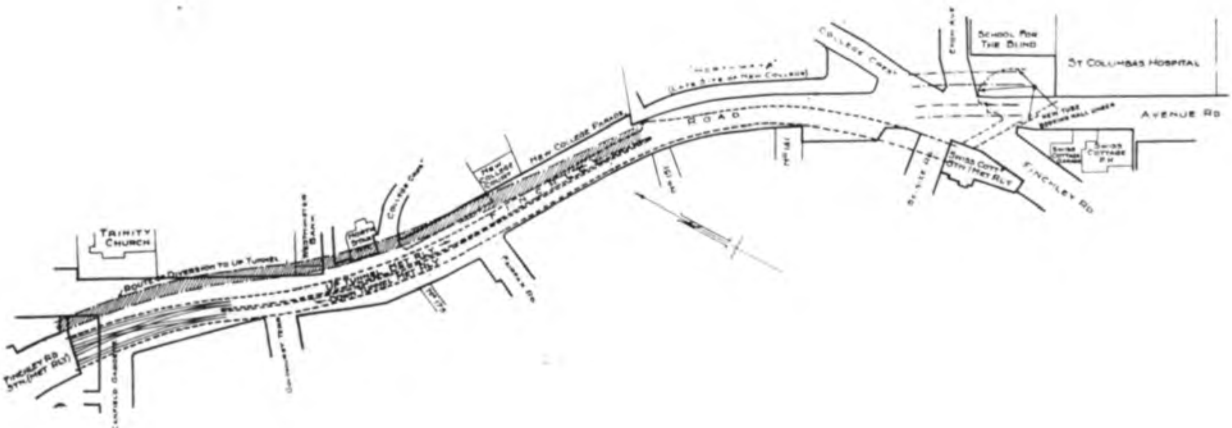

Fig. 1.—Plan of Route.

Fig. 1 indicates the route of the Board's operations so far as it affects Post Office plant between Swiss Cottage and Finchley Road stations. Although the distance is comparatively short, being only 600 yards, four distinct types of operations were involved in the provision of the additional tunnels under this portion of the road, as follows :—

1. Between the surface lines beyond Finchley Road station and a point near Trinity Church, the new line was provided by tunnelling under the existing shop cellars and under this portion of the roadway.

2. From this point to a point opposite 151 Finchley Road the new tunnel was being provided by the " cut and cover " method, involving the provision of temporary roadways to carry the traffic. Fig. 2 shows a portion of this work in progress.

3. From 151 Finchley Road to a point south of Swiss Cottage station the levels of the road were altered ; the existing roadway was reinforced with concrete ; and the underground station and new tunnels excavated under the existing road.

4. From this point southward the new " Tube " line was cut by the Greathead shield method. It may be of interest to describe this method of cutting tunnels in the sub-soil. The Greathead shield consists of a suitable number of rams mounted on a circular steel framework so that the whole diameter of the

Fig. 2.—Provision of New Tunnels by Cut and Cover Method.

tunnel is covered by the cutters attached to the rams. In railway work the running tunnels are normally 12 ft. internal diameter, and the shield carries ten rams of not less than 7 in. diameter, capable of exerting a maximum thrust of 385 tons. The station tunnels are normally 22 ft. diameter and require not less than 22 rams. The procedure of operation has varied somewhat since the original introduction of the method, but the latest practice is to excavate practically the entire surface of the tunnel face within the inner diameter of the shield, the rams then being used to clean off the excavation prior to the insertion of the cast steel segments. These segments vary in width from 20 in. in running tunnels to 18 in. in a 22-ft. tunnel. The rams are worked until the excavation cleared is equivalent to the width of the segment, the pressure then being released and the shield pushed forward exposing sufficient space for the insertion of another section of the steel segments. When these are bolted in position, the shield is immediately set up against the edge with an intervening packing to hold the neat Portland Cement grout. Considerable importance is attached to the grouting of the external diameter of the steel segments. On a twelve foot tunnel one iron ring of two feet normally requires 7 cwt. of cement. This grouting is forced in at a pressure of not less than sixty lbs per square inch. In addition to being mechanically the strongest construction it is claimed for this method that no settlement can occur in the surrounding sub-soil.

It is of considerable interest to note the very simple arrangements made for controlling the travel of the shield. The methods adopted are designed in such a way that a Ganger or leading miner responsible for the working of the shield can directly read a set taken by the shield in every plane. To enable the tunnel to be kept straight guide rods are hooked on to the shield and extended back into the tunnel for a distance of 30 ft. The principle of these guide rods is based on the rein control of a horse; the ends of the guide rods are marked in feet and inches and a fixed mark on each side of the tunnel indicates exactly the rate of travel of each side of the shield and immediately detects any tendency to lead to one side or the other. The Ganger has this guide mark under his observation during the whole period the rams are working and any tendency to set in the wrong direction is corrected by shutting off one or more rams on the leading side. Where a curve is required on the running tunnel, the expedient is adopted of having a shrunk rod which is used on the inside of the curve in place of the standard rod. These shrunk rods are marked to give the same standard reading against the marker, but the actual measurement is shorter by the amount of curvature required in the tunnel. The Ganger has only a direct reading to consider throughout the operation. The gradient levels are fixed by insertion of what is termed a " fiddle " on the horizontal plane which is used in conjunction with the " bob lines " suspended from the top centre of the tunnel. It will thus be seen that the somewhat complicated problem of control of the direction of the tunnel is resolved to the simplest of readings as regards to the actual operations by the workmen.

The scheme also provides for changing over the existing track to the new tunnels and linking up the existing track to the new tube line. Fig. 3 shows the work in progress over the existing track. The temporary shields to protect the trains while the old tunnels were demolished, are of interest.

In addition to the Transport Board's proposed operations it was known that the local authorities contemplated widening Finchley Road, and creating a round-about over the Swiss Cottage station site. Although the latter scheme had not been laid down in detail, it was sufficiently advanced to complicate the problem of the provision of the railway and consequent diversion of all the existing Post Office plant on the route concerned. The problem was further complicated by the severe gradients that existed in the side roads running east of Finchley Road. The difficulty involved an alteration in road levels including the sewer and gulley connections when the road was widened.

FIG. 3.—WORK IN PROGRESS OVER EXISTING TRACK.

When it is realised that the railway tunnels are placed only two to four feet from the surface of the road and extend across the entire width of the carriageway, the problem of accommodating all the requirements for other services appeared to be insurmountable.

Organisation of the Work.

The Post Office played a leading part in the initial stages of the preparation of the scheme and, at the request of Sir Harley Dalrymple Hay, the consulting engineer employed by the London Passenger

Transport Board, made the necessary trial holes and prepared the initial plans of the section concerned. It was immediately apparent that a considerable amount of give and take would be necessary from all statutory undertakers, and these included the Metropolitan Water Board, The Gas Light and Coke Co., the electricity supply undertakings, the Hampstead Borough Council for local drainage, the London County Council for main drainage, in addition to the Post Office. The police and Transport Board were concerned mainly with the regulation of traffic.

Sir Harley Dalrymple Hay arranged a series of conferences which were continued throughout the major operations and, at these conferences, very valuable contacts with the representatives of other undertakings were made and maintained during the execution of the work. It was found that these contacts formed an essential and very valuable asset in performing the work and it is considered that works of such magnitude cannot be efficiently organised without them.

When the question of the design of the new Post Office routes were determined the following fundamental principles were adopted and adhered to throughout the scheme :—

1. Any route chosen should be direct.

2. The manhole positions should be placed to facilitate jointing not only on through cables but also on existing plant and provide the necessary flexibility for all types of cabling.

3. Abnormal depths should be avoided.

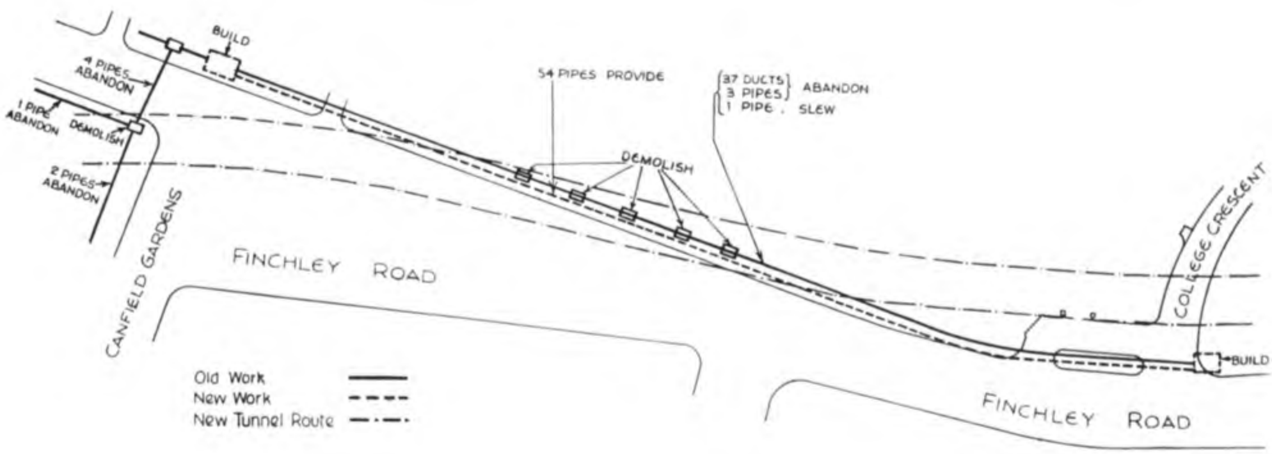

FIG. 4.—PLAN OF THE FINCHLEY ROAD DIVERSION.

In view of these principles it was decided at the outset that steel pipes formed the only reasonable method of providing the conduits and that these must be laid above the railway works over the whole of the route.

It should be explained at this stage that owing to the method of working adopted by the Transport Board it was not possible to carry out the whole operations as one job, and the work was therefore divided under (a) the Finchley Road diversion, (b) the Swiss Cottage diversion. Figs. **4** and **5** are simplified versions of the plans. From a Post Office point of view this involved a very considerable increase in jointing work as the whole of the trunk and junction

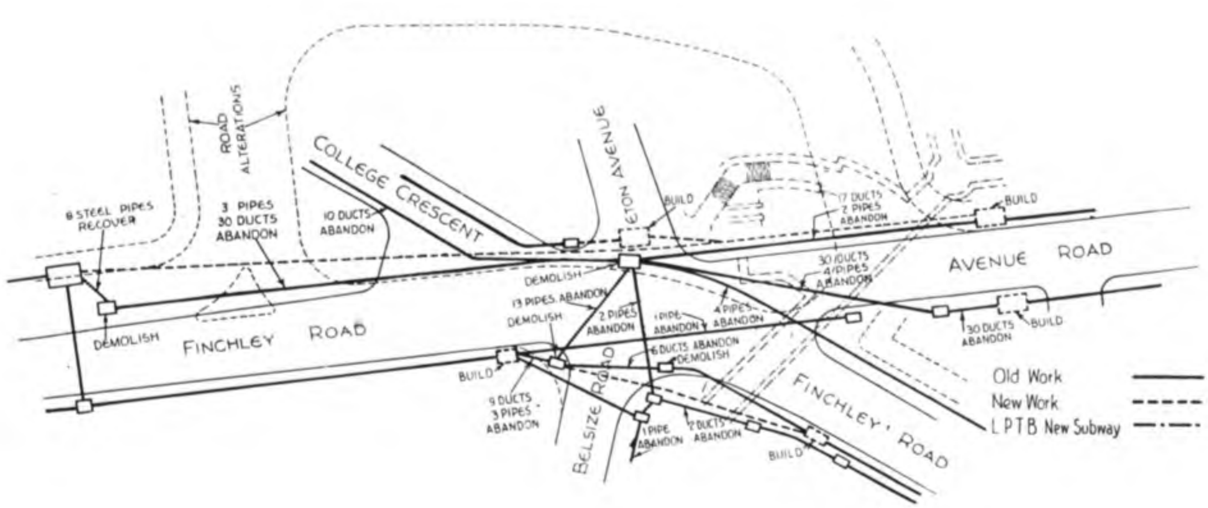

FIG. 5.—PLAN OF THE SWISS COTTAGE DIVERSION.

Fig. 6.—Tunnel under Construction.

cables totalling twenty-eight had to be diverted in two stages instead of a single change-over.

Reconstruction of the Duct Route.

The construction of the new Post Office route from Trinity Church manhole to Avenue Road as a single unit was quite impossible in the initial stages due to the very serious congestion and the amount of preliminary clearing that would have been involved, especially at the Swiss Cottage end. In addition, a considerable portion of the new route led through the gardens and forecourts of existing houses and shops on the east side of Finchley Road. The design of the underground station at Swiss Cottage had not reached such a stage that depths could be given and the line of route finally determined. The Finchley Road portion was therefore put in hand in advance and a group of steel pipes was laid as indicated on the plan (Fig. **4**). The only novel feature in this construction was the careful selection of the position and depth of the pipes in order to allow sufficient space for plant belonging to other undertakings. The importance of this may be gauged by the fact that clearances were sometimes only 2 or 3 in. The groups of pipes were clamped together in formation with steel bars at 10 ft. intervals to add rigidity. This was necessary because at a later stage the Transport Board excavated right up to the steel pipes, which, in fact, carried part of the roadway while the new tunnels were being constructed underneath. To secure both the safety of the Post Office plant and to support the roadway very careful timbering had to be done at close intervals while the permanent retaining walls of the railway tunnel were built between the wooden baulks. These can be seen on the left of Fig. **3**. Before the timbering was removed 18-in. brick piers were built from the top of the tunnel to the steel pipes at 7 ft. intervals. The load being thus transferred to these permanent piers, the timbering was removed and the retaining walls completed.

It is of interest to note that the whole of the tunnel walls, including those in the Underground station, were built with engineering bricks and walls up to 4 ft. thickness were provided in some places. Fig. **6** shows one of these tunnels under construction.

The replacing cables were then run and diversions made between 141 Finchley Road and Trinity Church (see Fig. **1**) to enable the Board's contractors to excavate and cut away the existing Post Office route. So close was the co-ordination that old routes were cleared of cables and cut away within two or three days of completion of the diversion, and throughout the operations no serious delay was occasioned to the operations of the other contractors. Fig. **7** shows the new tunnel being cut under the Post Office manhole which is in the recess at the top of the photograph. This manhole was subsequently demolished to permit the completion of the tunnel. It is also of interest to recount that many thousands of circuits were diverted without any complaint being received or circuit being lost during this operation. This reflects considerable credit on the staff employed.

On completion of the Finchley Road portion of the work the Swiss Cottage section, as shown in Fig. **5**, had to proceed immediately, but many consultations and arrangements were made before this could be put in hand. Considerable diversion of both gas and water mains up to 24 in. had to be made, some on a temporary basis, to provide the space required by the Post Office. At the Swiss Cottage junction, six important roads converge of which four are busy bus routes, and the remaining two carry very heavy traffic. Forty-two steel pipes were laid in this portion of the route after securing the diversion of the gas and water mains indicated above, close co-operation with the traffic authorities being necessary.

Fig. 7.—New Tunnel cut under P.O. Manhole.

A conference on site with the representatives of the Police Commissioner from Scotland Yard, road authorities, Transport Board, etc., was held and arrangements made to close three roads to traffic concurrently. To secure the closing of such main traffic roads in London it was necessary to work to a very exact time-table which was determined at least a fortnight beforehand to enable the various authorities to make their arrangements, including such items as the fixing of diversion signs, alteration of bus stops, etc. Arrangements were made to close College Crescent for one week to excavate the road, lay the pipes and reinstate the surface and to re-open for traffic at 8 a.m. on the following Monday morning. Eton Avenue was closed for a week under similar conditions. Avenue Road was the next to be closed and the period was extended to one month. The only traffic allowed through was that proceeding to the hospital. The Avenue Road alterations included the provision of two large manholes, the taking up of the east side footway entirely, and the provision of a road crossing opposite St. Columba's Hospital. The whole of this work was performed exactly to time and the only anxiety was caused in the Eton Avenue crossing when it was found that a 24-in. gas main collar was in the way of the route to be taken by the Post Office pipes. It speaks very highly of the co-operation given by the Gas Company that this collar was cut out and a length of pipe replaced by a 24-in. steel main within twenty-four hours. The unforeseen difficulty resulted in the necessity for close co-operation in the laying of the pipes and the reinstatement of the road by the following Monday morning. The reinstatement was performed by the Hampstead Council (by using Cement Fondu) between Saturday night and Sunday night, and the permanent wooden blocks were reinstated and the road opened for traffic by Monday morning as scheduled.

Considerable care had to be taken in laying the Post Office pipes over the area scheduled for the new underground station. It was arranged with Sir Harley Dalrymple Hay that these pipes should be carried in the new station roof, which was only 22 inches below the final road level. It was essential, therefore, that their depth and alignment should be exact and should not vary by an inch over the whole route. It is of interest in connection with the construction of the new station, that a 42-in. water main existed across the proposed site. This had to be diverted previously by special subway construction under the position of the railway tunnel and brought up to join the existing system by a ramp at an easy angle. In addition to this, the exact line of the water main had to be fixed in a position to secure clearance for the Post Office route. Incidentally, Sir Harley Dalrymple Hay suggested that the Post Office pipes could also be accommodated in the subway but this was refused because of the abnormal depth of the connecting manholes and the impossibility of gaining access to the plant. The alternative suggestion of building the Post Office pipes in the station roof was made by the Post Office representative and accepted by Sir Harley Dalrymple Hay, and is much more satisfactory from the Post Office point of view.

A difficulty was encountered in laying the pipes in the Avenue Road footway after the diversion of the gas, water and electric light mains. The existing Post Office cables, including the 1st and 2nd Birmingham cables, were carried in iron pipes at shallow depth and it was not possible to lower or slew them to provide the necessary clearance. The difficulty was overcome by breaking away the pipe route and enclosing all the cables in a temporary iron trough. This gave the exact clearance required and the permanent steel pipes were laid immediately on top of the troughing. After the diversion of the circuits to the new route the old cables were pulled out in conjunction with the Transport Board's excavations when they exposed the pipes and iron troughing by cutting away underneath.

The operations at Swiss Cottage involved the provision of ten steel pipes outside the existing Swiss Cottage station over the site of the proposed subway entrance to the new station. The only difficulty that arose in connection with this work was the provision of the manhole outside the existing station when an existing subway leading to the platform was found to foul the position required for the manhole. This difficulty was overcome by securing consent of the Transport Board to cut away a portion of the subway in order to build up one wall of the manhole.

Diversion of Cable.

The work of providing the new cables required special thought and planning. It was necessary to specify the duct and the position for each cable in the manholes in order to give the best jointing positions and to maintain proper access for all future cables. This problem was most difficult where the duct ways changed formation in addition to the variations in

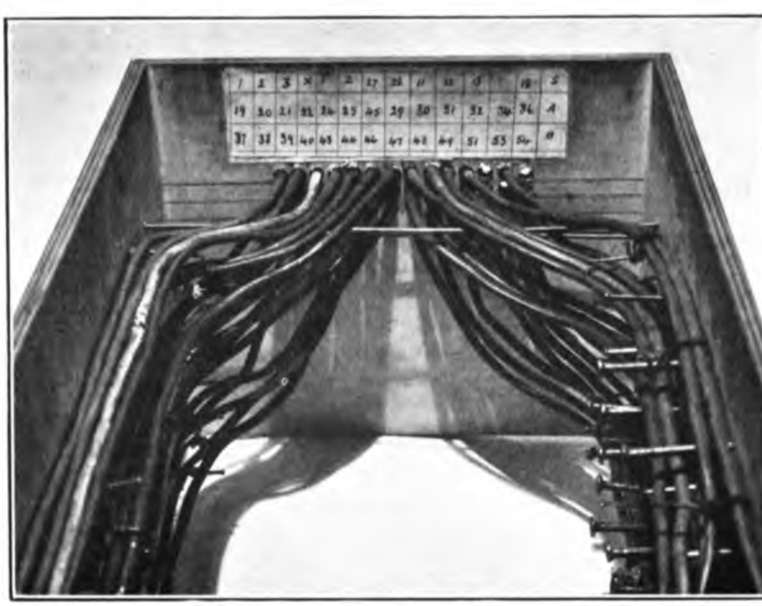

FIG. 8.—MODEL OF MANHOLE AT TRINITY CHURCH.

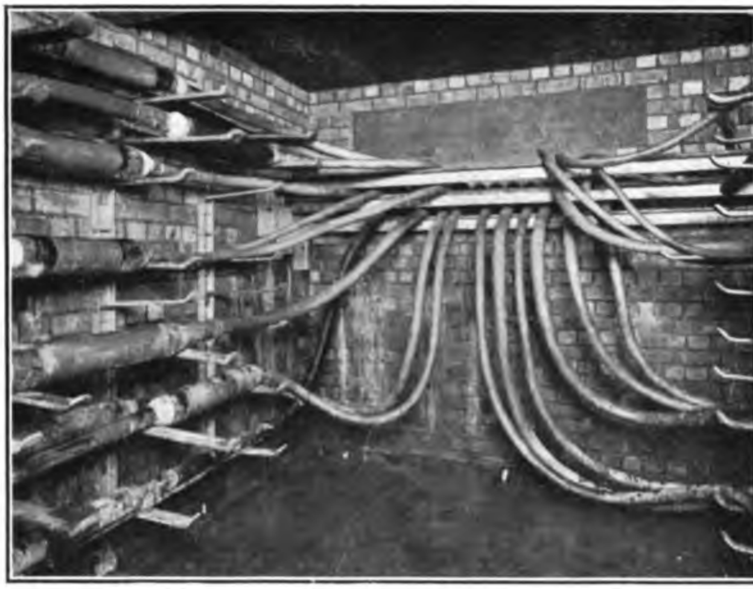

FIG. 9.—COMPLETED TRINITY CHURCH MANHOLE.

levels in the routes entering the manholes. Such conditions were met where the new route joined the old duct route at Trinity Church and Avenue Road. The problem was solved by the method which has now become standard London practice with complicated manhole layouts; i.e. a small model of the manhole was constructed in plywood and lengths of 1 pair cable used to represent the cables to be provided. The various possible arrangements were set up until the best was determined. A plan was then prepared indicating the position allocated to each cable. Fig. 8 shows the model used on this work. A special arrangement of cable bearers was required at the manhole where the duct levels varied considerably, and three iron bars of T section were provided to take the weight of the vertical drop of cable to the lower duct level. Fig. 9 shows the cable layout as completed in the Trinity Church manhole.

The recovery of cables constituted a work of considerable magnitude and over 250 tons of cable were withdrawn. This was not all directly connected with the Board's operations. Advantage was taken of the opportunity to break down on the route leading to the old Hampstead exchange to gain access to a number of derelict cables, which it had been found impossible to recover previously.

In connection with the recovery and abandonment of the old plant it was necessary to abandon ten manholes and some consideration had to be given to the precautions to be adopted. In consultation with the Surveyor of the Borough Council it was agreed that the manholes could be filled with rubble, the shafts broken down, and the road reinstated over these.

Conclusion.

The above outline gives a good example of the effective use of planning in advance of operations. The necessary works control was maintained by field contact between all the supervising officers concerned and day-to-day progress was indicated on a straight line diagram of the new cables showing the date each length was drawn in and each joint commenced and completed. The results obtained substantiate the fact that such methods are superior to remote control when a work of such magnitude and complexity is concerned.

This job demonstrates the value of utilising steel pipes in congested areas; without the use of these, it would have been impossible to have performed the work and maintained the same route, and the diversion by any alternative route would have been of such magnitude as to have been prohibitive. In addition, the steel pipes being reasonably flexible and individual can, if necessary, be divided to overcome obstructions and this practice avoids abnormal depths. It is also possible, as was done in this work, to build-in steel pipes into existing tunnels or similar obstructions and, it is suggested, serious consideration should be given to the adoption of this type of construction in preference to the utilisation of ducts at great depths in towns, with all the attendant disadvantages. Deep manholes are almost invariably water-logged and the removal of water in busy thoroughfares is not only a continual expense but a very considerable nuisance to the general public, and the use of motor pumps continuously running in built-up areas may give rise to serious complaints.

It has also been demonstrated that the value of co-ordination and close contact with other undertakers and public authorities can secure very amicable working and also effects very considerable savings in cost.

It speaks well for the Post Office organisation that this large volume of additional work over and above the normal day-to-day duties was carried by the existing staff and organisation, as no special provision was made for augmenting the supervising, drawing office or jointing staffs. There is also the aspect that the incidence of such works constitutes a very serious drain on the available manpower, with a comparatively small immediate benefit in additional services, although a well constructed layout has been provided for the future.

In view of the schemes now being scheduled under the 5-year road plan and the further road works suggested by the "Bressey" report, it is apparent that work similar to the above will be recurring for a considerable period. To obtain the best results special studies and preparations well in advance of the works should be made by competent officers stationed, preferably, either at the Chief Regional Engineer's Office or at Headquarters, in order that the full benefit of effective co-ordination may be realised.

The authors are indebted to Mr. Fitzgerald of Sir Harley Dalrymple Hay's staff for the loan of photographs of the Transport Board's operations and to several members of the staff in the North West Area for their co-operation in preparing these notes.

Non-linear Distortion of Music Channels with particular reference to the Bristol-Plymouth System

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U.D.C. 621.395.8

An introduction defining non-linear distortion is followed by a description of the measurement of this form of distortion by combination tones. Details of the tests made on the Bristol-Plymouth music channels are given.

Introduction.

PROGRAMMES transmitted over music channels are subject to the following distortions: (*a*) attenuation distortion; (*b*) delay distortion; and (*c*) non-linear distortion.

The first of these, attenuation distortion, is characterised by a variation of the overall loss of the system with frequency. It is measured with the system operated under steady state conditions by a series of signals of sinusoidal wave form, of equal level, but at different frequencies extending over the transmitted frequency band.

Delay distortion is due to variation of the transmission time of the system with frequency. The delay is usually expressed in milliseconds and is the difference between the time of propagation of the envelope of a wave at any frequency and that of a wave at a specified frequency, usually 800 cycles per second.

The amounts of attenuation and delay distortion which are permissible on music channels have been established and limits regarding them are given, for instance, in the proceedings of the C.C.I.F. The performance of the Bristol-Plymouth music channels in these respects has been described in an earlier article in this JOURNAL.[1]

Non-linear distortion is due to the transmission properties of the music channels being dependent on the instantaneous magnitude of the transmitted signal. It is characterised by the generation of harmonic frequencies of any single parent frequency, and by the production of sum and difference frequency tones when two or more parent frequencies are present. It gives rise to amplitude distortion which is a measure of the variation of the overall loss of the system with the input signal level, measured under steady state conditions, and to flutter, which is the variation in the overall loss of the system at one frequency due to the simultaneous transmission of a signal at another frequency. As will be explained later in the article, most attention is being directed, at the present time, to the measure of harmonic and combination tones when assessing the performance of music channels with respect to non-linearity.

There is, however, very little information yet available regarding the amounts of harmonic and combination tone distortion which are permissible. The C.C.I.F. accordingly requested the member administrations to carry out certain tests in order that provisional limits could be established for these quantities (Question 14, 1936/38). The Post Office, in conjunction with engineers of the British Broadcasting Corporation, accordingly carried out a number of quantitative tone measurements and correlated these to appreciation tests carried out with direct programme material. The results of these tests form the subject of this article. Summaries of the information available from other sources, which have direct reference to this problem, have also been included.

[1] *P.O.E.E.J.* Vol. 31, p. 280.

DISTORTION DUE TO NON-LINEAR CHARACTERISTICS

Methods of Measurement.

It has been usual, until comparatively recently, to estimate the total disturbing effect of non-linear distortion either by a measurement of the input/output characteristic (in terms of r.m.s. quantities) or by a measurement of the amount of harmonics produced by the system, when transmitting a single sinusoidal signal. In regarding these two tests as alternative means of assessing the same distorting effect, the assumption was made that a knowledge of the shape of the (r.m.s.) input/output characteristic necessarily conveyed a knowledge of the amount of harmonics likely to be generated by the system. For the earlier and simpler types of circuits, this assumption may have been true but it does not apply to the modern systems in use.

Acoustical engineers have been faced with the same problem for a variety of types of electro-acoustic apparatus and have formulated two definitions to assist in the discussion of the subject, viz.:

(1) Amplitude Distortion—characterised by a lack of constancy of the ratio between the r.m.s. value of the response of the system and that of the stimulus, at different amplitudes of the stimulus.
(2) Non-linear Distortion—distortion resulting from a lack of constancy of the ratio of the instantaneous values of the response and the stimulus. It is characterised by the production of harmonic and sum and difference tones.

It has already been appreciated that, with modern systems, the amplitude distortion may be reduced to a very small amount and, as such, may probably be ignored as a distorting influence. The non-linear distortion is not eliminated by this reduction of the amplitude distortion, and remains as a distorting influence which must be determined by the measurement of the characteristic tones.

It is well known that the tone colour of a musical sound is dependent on the harmonic content. Increase of harmonic content, therefore, will lead to a change of tone colour but does not necessarily give rise to the harshness which is characteristic of non-linear distortion. This harshness, which is the most important factor, is very largely caused by intermodulation between signals at different frequencies, leading to the production of summation and difference tones of second, third and higher orders depending on the non-linear characteristics of the system.

Asymmetric distortion which is characteristic of certain types of thermionic valve, dry-plate rectifiers, etc., and which leads to the generation of even order harmonics, also leads to the production (from two input signals p and q) of the summation and difference terms of second order $p \pm q$ (and higher order even terms). The $p \pm q$ terms are referred to as " quadratic combination tones " and, for reasons which are explained later, it is customary to consider only the $p - q$ term.

Symmetrical distortion which is characteristic of certain types of thermionic valve, iron losses, etc., and which leads to the generation of odd order harmonics, also leads to the generation of summation and difference terms of third order $2p \pm q$ (and higher order odd terms). The $2p \pm q$ terms are referred to as " cubic combination tones " and in this case also it is customary to ignore the summation term.

Distortion caused by spurious frequencies depends on the position these occupy both in the transmitted frequency range and in relation to the parent tones. This is discussed in detail by Fischer and Lichte[2] and the importance of spurious frequencies generated by parent tones p and q for which $p >> q$ is pointed out, since the $p \pm q$ terms then lie in the immediate neighbourhood of one of the parent tones. Under this condition, the authors state that distortion is audible when the combination tones are in the order of 1-2 per cent. of the parent tones.

The same authors compare this to variation of tone colour due to generation of harmonic frequencies which, they state, is audible for amounts of 1-6 per cent., depending on the parent frequency. In this case, the audible sensation is not such an unpleasant one as is obtained for the smaller percentages of combination tones. The above percentage values are only observable by direct comparison with the undistorted original. The relevant quantities for detection without comparison are, according to this authority, 10-20 per cent. of harmonic and 5 per cent. of combination tones.

A further reason why harmonic distortion is not of so much importance either in the causation or measurement of non-linear distortion rests on the fact that the harmonics of the higher frequencies fall outside the transmitted frequency range of the system.

At the present time, therefore, measurement of combination tones appears to offer the best means of determining the performance. It suffers from the disadvantage that it is a measurement which is not normally made in line practices and for which special apparatus is required. It becomes necessary to decide, therefore, what combination tones shall be measured, with a view to simplifying the measurements.

Since the $p \pm q$ term is a measure of the asymmetric distortion and the $2p \pm q$ term of the symmetric distortion, the higher order terms may be and are generally neglected.

The masking effect of sounds enables one to simplify this a stage further. It is well known that, for two tones of equal loudness, the tone of lower frequency tends to mask the tone of higher frequency. The effect may be observed in the judgment of music distortion, wherein spurious frequencies which lie below the parent tones have a greater annoyance factor than those which lie above them.

It is usual, therefore, in measuring combination tones, to ignore the summation terms $p + q$ and $2p + q$ since these will in many cases fall outside the range of transmitted frequencies or, where they fall inside the range, are more or less masked by the parent tones.

By general agreement, the input parent frequencies are arranged for measurement purposes, to be of equal magnitude, and the effective voltage of the difference tones is expressed as a percentage of the lesser of the parent tones as measured at the output of the system. These factors are referred to as the " Coefficients of Difference Tones."

Correlation of Measurement and Judgment.

Before it is possible to set limits as to the amounts of combination tone products that are permissible, it is considered that a large amount of experimental investigation has yet to be completed.

In an investigation into the intermodulation products of thermionic valves, in which the distortion is independent of frequency, Harries[3] quotes the following values :

	Difference Tones
High quality transmission	$2\frac{1}{2}$ per cent. max.
Good commercial quality	quadratic $\ngtr$ 15 per cent.
	cubic $\ngtr$ $2\frac{1}{2}$ per cent.

These figures are at least sufficiently useful to establish the order of the factors concerned.

An investigation carried out by F. Massa[4] also on distortion produced by thermionic valves and therefore independent of frequency, gave the following results :—

Harmonic mainly	*For a detectable change of quality :* *With comparison*		*Without comparison*	
Frequencies up to	*2nd* %	*3rd* %	*2nd* %	*3rd* %
14,000 c/s	5	3	10	5
8,000 c/s	5	5	10	7
5,000 c/s	12	>10	17	>10

It will be noticed that cubic distortion was found to be more serious in this case than quadratic. It is very possible in the type of system employed for these tests that the cubic distortion would tend to increase with input level at a higher rate than the quadratic, which would partly account for the result obtained.

The fact that the requirements are most severe for

[2] Fischer and Lichte. *Tonfilm*, p. 246.

[3] *Wireless Engineer*. February, 1937.

[4] Proc. I.R.E. May, 1933.

the wide frequency bands would tend to suggest that important distortion products are to be found in the upper register, which is not in full accord with the argument regarding masking.

A very thorough investigation has been carried out by Braunmuhl and Weber[5] in which many interesting results were discovered. The tests were carried out under laboratory conditions and it was possible to arrange for various shapes of the curve of the coefficient of difference tones against frequency, to simulate those obtained in practice on the various parts of a complete sound system. It was also arranged to study the effects of quadratic and cubic distortion separately.

The method of classifying the amount of distortion during the listening tests was in accordance with the following grading :

0—no audible distortion.
1—just audible by direct comparison.
2—audible without close attention.
3—clearly audible.
4—greatly distorted.
5—intolerable.

The coefficients are quoted for the grading 1. The following is an extract of the results obtained :

(*a*) For pure tones it was found that the intermediate frequencies are most sensitive. Only the quadratic distortion was investigated and the coefficients (k) were found to be :

p		*k*
100 c/s	.. ..	2%
1,000 c/s	.. ..	0·7%
4,000 c/s	.. ..	4%

(*b*) For double tones, the following coefficients of quadratic distortion were obtained :

p	*q*	*p-q*	*k*
800 c/s	1,200 c/s	400 c/s	<<1%
800 c/s	900 c/s	100 c/s	0·7 %
800 c/s	850 c/s	50 c/s	1·3 %

The distortion is clearly dependent on the relative position of the p − q and possibly of the p + q term.

(*c*) Tests were made of distortion of speech and music programmes with a network simulating the type of distortion coefficient-frequency characteristic which is obtained on cable circuits. The following results were obtained for speech transmission :

For quadratic distortion .. k = 30 per cent.
For cubic distortion .. k = 22 per cent.

In these and other cases where the coefficient is variable with frequency, the k value, which still refers to grade 1 distortion, is the maximum value over the frequency range concerned. On cable systems, the maximum value usually occurs at the lowest frequency effectively transmitted.

The following values were similarly obtained for music transmission :

For quadratic distortion .. k = 20 per cent.
For cubic distortion .. k = 26 per cent.

It is further concluded that, for this type of system, distortion will be inaudible on ordinary music and just detectable on pure tones where k is less than 2 per cent. for the intermediate and higher frequencies, rising to about 15 per cent. for frequencies below 100 c/s.

It is now possible to pass on to the actual non-linear distortion measurements made on the Bristol-Plymouth system.

Bristol-Plymouth Non-Linear Distortion Measurements

All the measurements described in this section were measured on the loop length of 250 miles.

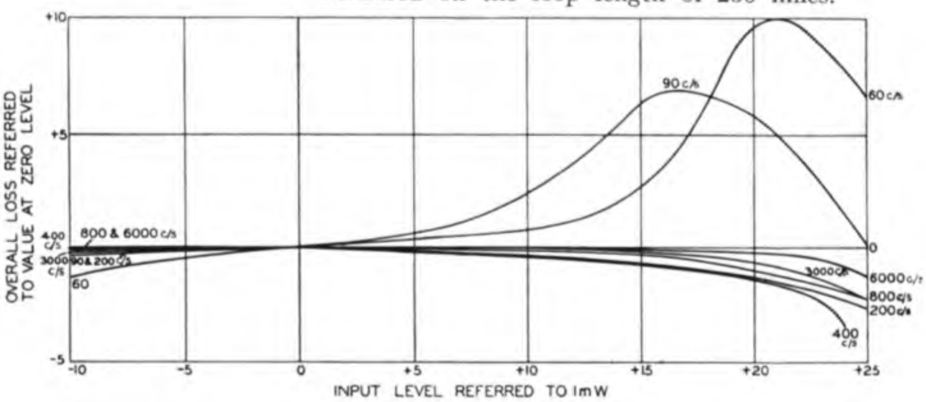


Fig. 1.—Amplitude Distortion Characteristics.

(*a*) *Input/Output Level Characteristic.*

In Fig. **1** are shown the characteristics obtained for frequencies over the range of 60 to 6,000 c/s. The changes of level were obtained by simultaneous adjustment of sending and receiving attenuators, thus eliminating the errors in the measuring apparatus by maintaining a constant deflection.

(*b*) *Harmonic Content.*

These measurements and those of the combination tone products which follow were made by a wave analyser having a frequency range of 0 to 17,000 c/s with a frequency discrimination of 60 db. at 60 c/s separation throughout the frequency range.

Fig. **2** shows the second harmonic as a percentage of the fundamental wave measured at the output of the loop, in terms of the input level to line, and Fig. **3** shows the harmonic at various input levels in relation to frequency.

Figs. **4** and **5** show the third harmonic in the same manner.

In Fig. **6** are shown curves of total harmonic at various frequencies in terms of the sending level, and in Fig. **7** similar curves are given at various levels in terms of frequency.

In all the foregoing measurements the abnormal behaviour of the system at low frequencies will be observed.

(*c*) *Coefficient of Combination Tones.*

Coefficient of quadratic difference tone. This was measured in the manner requested by the C.C.I.F.,

[5] *Akustische Zeitschrift.* May, 1937.

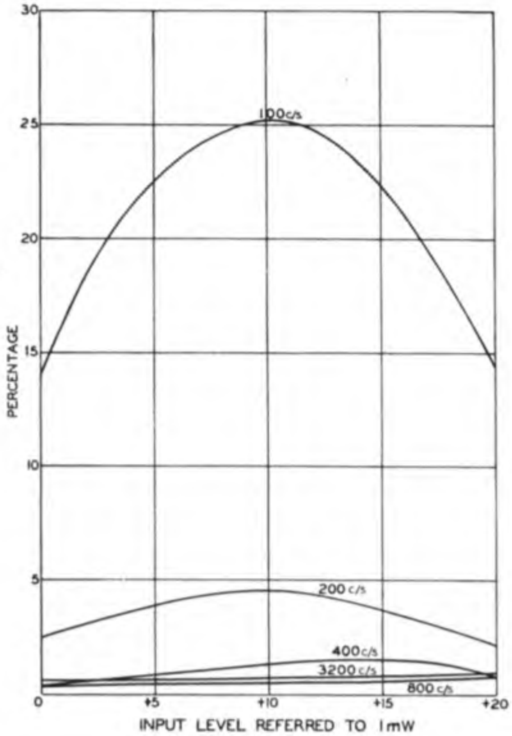


Fig. 2.—Percentage of 2nd Harmonic.

which consisted in applying two pure tones p and q of equal magnitude and separated by 60 c/s. The difference term is clearly one of 60 c/s, which is maintained constant while p and q are made to traverse the frequency range at the constant separation. The summation term is neglected throughout.

At the input, the two frequencies p and q were injected via a hybrid coil at the nominal level of the test. In this way interaction between the oscillators is avoided and the combined energies become that of the nominal level of the test.

The magnitudes of the parent terms p and q and the 60 c/s difference term were measured at the output of the loop by the wave analyser. The percentage of p − q to the smaller of the parent tones was taken and referred to the mean frequency at the nominal level of the test.

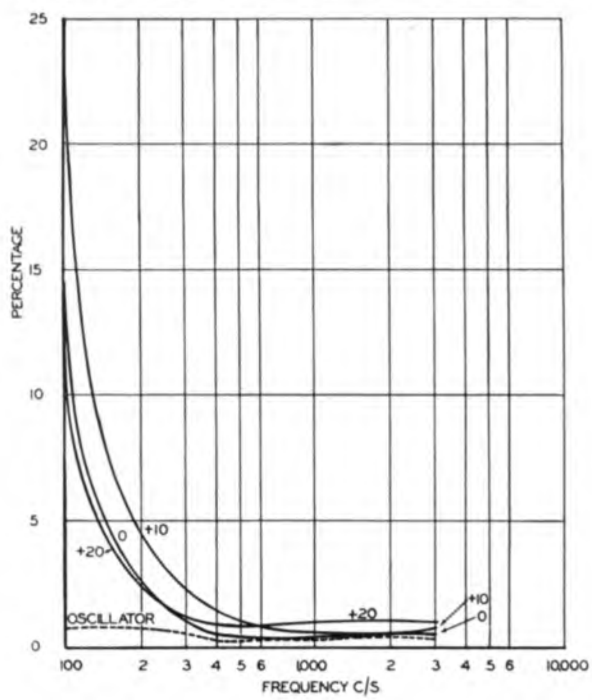


Fig. 3.—Percentage of 2nd Harmonic.

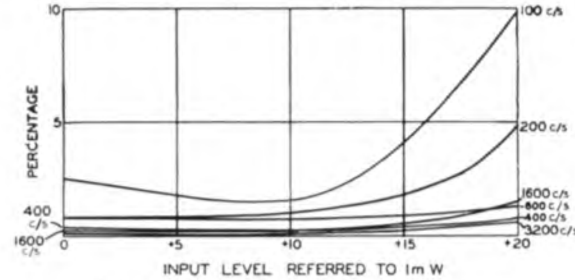


Fig. 4.—Percentage of 3rd Harmonic.

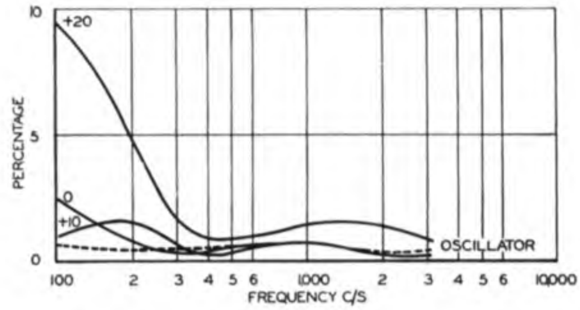


Fig. 5.—Percentage of 3rd Harmonic.

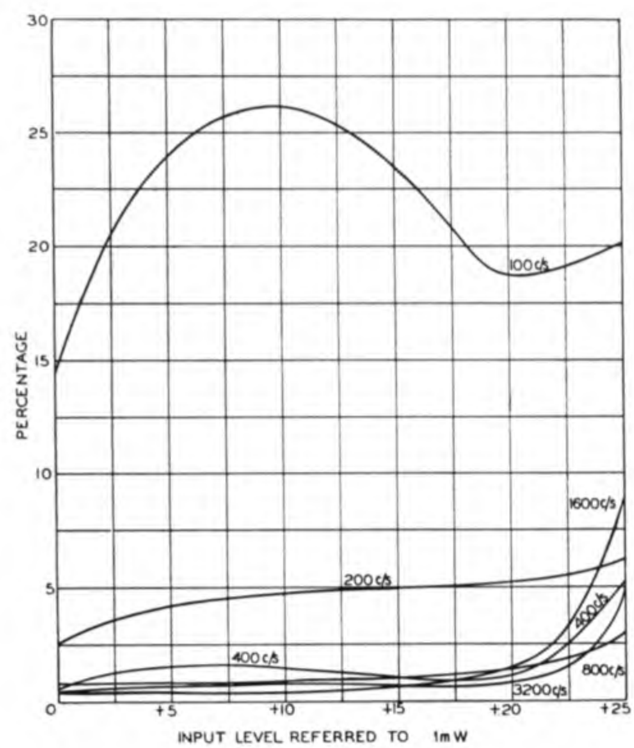


Fig. 6.—Percentage of Total Harmonics.

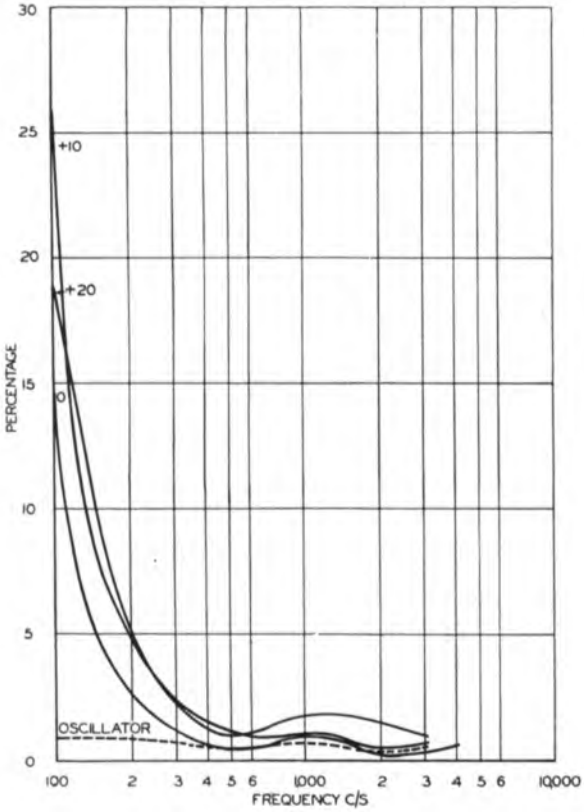


Fig. 7.—Percentage of Total Harmonic.

Fig. **8** shows the coefficient of quadratic distortion at various frequencies between 150 and 8,000 c/s in relation to the input level and Fig. **9** shows the same information expressed for various input levels in relation to frequency.

Coefficient of cubic difference tone. The coefficient of cubic distortion was not measured in the manner suggested by the C.C.I.F. which involved auxiliary square law detection of the intermodulation products and of the parent tones in order to maintain measurement of a constant 60 c/s wave, but by direct measurement of the 2p − q terms. The method employed, therefore, was to inject equal tones p and q as before and separated still by 60 c/s and to measure directly the p − 60 and q + 60 terms and relate the r.m.s. sum of these directly to the lesser of the parent tones at the output of the loop.

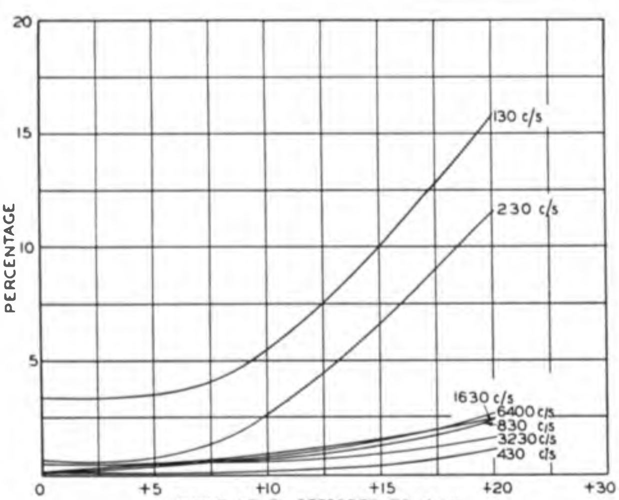


Fig. 8.—Percentage of Quadratic Difference Tone.

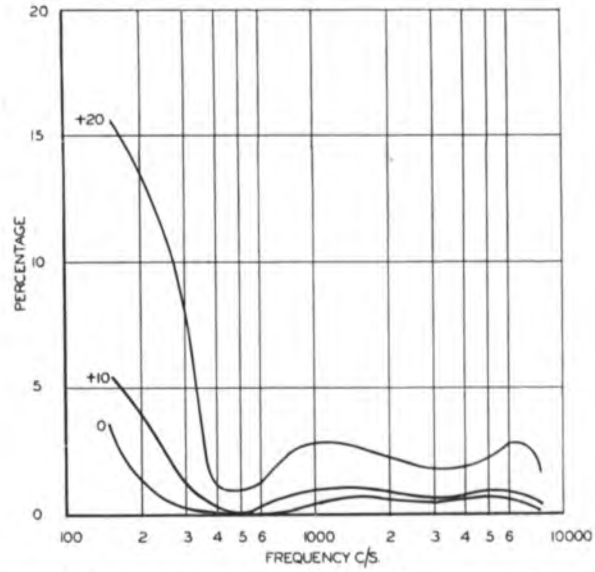


Fig. 9.—Percentage of Quadratic Difference Tone.

Fig. **10** shows the coefficient of cubic distortion at various frequencies in relation to the input level and Fig. **11** shows the coefficient at various input levels in relation to frequency.

The signal levels used in these tests are referred to

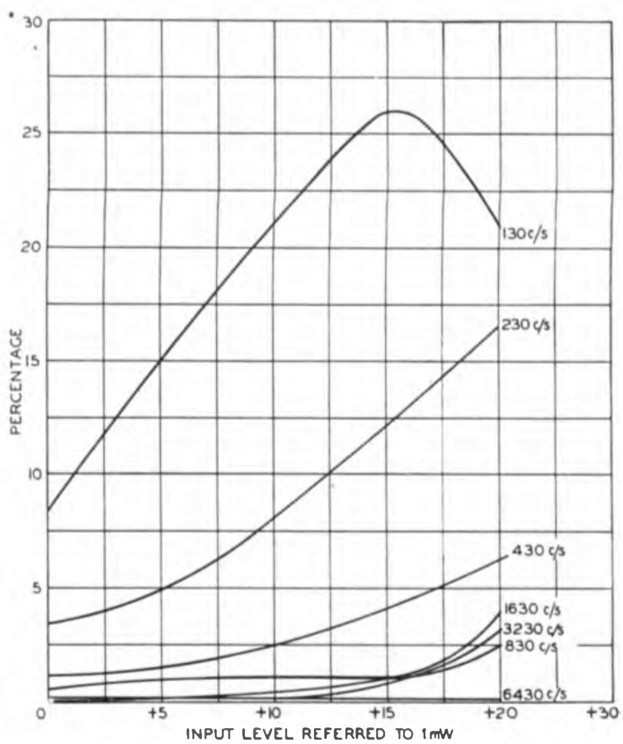


Fig. 10.—Percentage of Cubic Difference Tone.

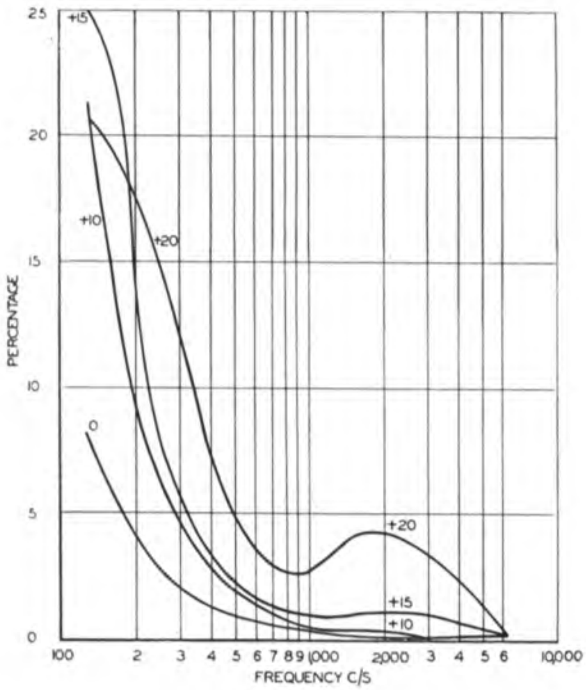


FIG. 11.—PERCENTAGE OF CUBIC DIFFERENCE TONE.

as tone levels in the next section, to differentiate them from programme levels.

Subjective Tests Carried Out at Bristol.

Judgment tests were carried out on the Bristol-Plymouth system to determine, for a system of this type, the degree of non-linear distortion that can be tolerated.

The volume of the programme sent to line was regulated by a "peak programme meter" conforming to the recommendations of the C.C.I.F.-U.I.R. (integration time 4 mS). This instrument is calibrated on steady tone so that it deflects to a point 8 db. below that to which programme of the same level will deflect it. The volume was regulated so that, in the normal condition, the peak voltage corresponded to the tone level of + 10 db. of the measured characteristics. Tests were made at levels above and below this normal value.

The programme material used consisted of speech, piano and small orchestral music and the test transmissions were carried out in conjunction with members of the B.B.C. in the Bristol studios. Eight observers compared the direct and distorted transmissions under good acoustical conditions. Two loudspeakers were employed, one, that normally employed by the B.B.C. for programme monitoring, and the other, that developed recently at Dollis Hill. The former is of special box construction having back and front openings and the latter is designed to operate in a totally enclosed and acoustically dead case. Although the tonal qualities of the two loudspeakers were characteristically different, yet both can be regarded as in the front rank of loudspeaker design. It is noteworthy that in the listening tests almost identical results were obtained with both loudspeakers. Since the distortion introduced into the sound system by the cable link was only an additional distortion to those inherent in the other parts of the system, the results are truly applicable only to the particular test conditions employed. Naturally every effort was made to maintain the other distortions as small as possible, and the fact that almost identical results were obtained with both loudspeakers would tend to confirm that the masking influence of other distortions was small.

Programme—	*Sending Level.*	*Braunmuhl-Weber Grading.*
(Normal = tone at + 10 db.)		
Speech	Normal	0 to 1
	5 db. above normal	1
Music	Normal	0 to 1
	10 db. above normal	1 to 2
	15 db. above normal	3
	20 db. above normal	4 to 5
Piano	Normal	0 to 1
	5 db. above normal	1
	10 db. above normal	3

It was considered that distortion of piano music was most pronounced on signal notes falling within the octaves above and below middle C (100 to 500 c/s).

Non-linear distortion was, in general, found to be more easily detected on speech and piano programmes than on more complex forms of musical sounds. It was always found that restriction of the upper transmitted frequencies between 6,500 and 8,000 c/s led to a marked reduction of the effects of non-linear distortion. This would also tend to indicate that important spurious frequencies lie in the upper register.

Fig. **12** gives a representation of the judgment of distortion according to the arbitrary gradings adopted in relation to the sending level.

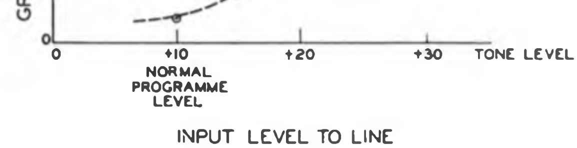


FIG. **12**.—ARBITRARY GRADING OF THE DISTORTION.

Discussion of Results and Conclusions.

The tone level at which the non-linear distortion was at grade 1 (just audible by direct comparison) was according to Fig. **12**, a level of + 15 db.

At this tone level the following distortion figures apply :

2nd Harmonic	(*a*)	up to 25 per cent. at 100 c/s.
	(*b*)	up to 3 per cent. for frequencies greater than 200 c/s.
	(*c*)	up to 1 per cent. for frequencies greater than 400 c/s.
3rd Harmonic	(*a*)	up to 5 per cent. at 100 c/s.
	(*b*)	up to 1 per cent. for frequencies greater than 400 c/s.
Quadratic distortion	(*a*)	up to 15 per cent. at 100 c/s.
	(*b*)	up to 7·5 per cent. for frequencies greater than 200 c/s.
	(*c*)	up to 1·5 per cent. for frequencies greater than 400 c/s.
Cubic distortion	(*a*)	up to 30 per cent. at 100 c/s.
	(*b*)	up to 10 per cent. for frequencies greater than 200 c/s.
	(*c*)	up to 5 per cent. for frequencies greater than 400 c/s.
	(*d*)	up to 1 per cent. for frequencies greater than 800 c/s.

Until more experimental information is available, any limits that are set must be regarded as provisional and should be substantially in accordance with the results given above. The following values were accordingly decided upon :

For the quadratic or cubic difference tones :

At any frequency between 100 and 200 c/s..	20%
At any frequency between 200 and 400 c/s..	5%
At any frequency between 400 and 800 c/s..	2%
At any frequency between 800 and 6,400 c/s..	1%

Where the quadratic and cubic difference tone measurements cannot be made, the total r.m.s. harmonic content should be measured and should be in accordance with the above table. It will be observed that these values are in general agreement with the conclusions reached by Braunmuhl and Weber.

It cannot be too strongly emphasised, however, that the limits are in the nature of tentative proposals and subject to revision when more evidence is available. Such evidence, it is considered, would best be obtained by investigations carried out on laboratory rather than field systems. The limits quoted, together with a report on the tests described above, were submitted to the C.C.I.F. Oslo meeting in June, 1938.

In conclusion, the very real assistance that was rendered by members of the B.B.C. staff who arranged for the availability of studios and programme material and co-operated in the listening tests, is gratefully acknowledged.

12-Circuit Carrier Cables—Temporary Intermediate Repeater Stations

The change in the method of provision for the main trunk network, from loaded underground cables with repeaters to unloaded cables worked on a carrier basis, coincided with a rapid rise in long-distance traffic. This introduced a difficulty from an accommodation point of view, since under the new scheme repeater stations are necessary at approximately half the spacing formerly required. This necessitated a large number of new repeater stations throughout the country.

For the buildings, depending upon their size, etc., it takes up to 32 months from the inception of a scheme to the availability of the equipment for service. This time includes selection and purchase of the site and the design and erection of the building. Cables and equipment can on the average be manufactured and installed in less than half that overall time.

A programme spread over three years is therefore being arranged. Sites and buildings being dealt with in one year, ducts and equipment in the next, and the cable in the third year.

In view of the demand for long trunks it has not been possible, in some cases, to wait for the permanent buildings, and use has been made of wooden huts of unit construction type ; each hut being 20 ft. long, 12 ft. wide and 15 ft. high to the ridge, internal measurements. These were designed as being a suitable standard size to cater for 1½—2 years' development on most routes while the permanent buildings are being erected.

Each temporary repeater station consists of three huts, one for the repeater apparatus, one for the batteries, used on a charge-discharge basis, and one for the power equipment, a prime mover (oil engine) being included where power supply is not available.

The illustration shows the arrangement at one of the temporary stations. The power equipment, batteries and repeater equipment can be seen through the open doors.

J.S.

Comité Consultatif International Téléphonique: Meeting of the Sub-Committees, London, December 1938

U.D.C. 061.3: 621.395.8   621.395.623   621.395.443.3

A resume is given of the matters discussed and the decisions reached at the sub-committee meetings concerning "quality of transmission" and "wide-band transmission" held in London in December, 1938.

Sub-Committee for the Specification of Quality of Transmission.

AT the Oslo meeting of the C.C.I.F., in June, 1938, a sub-committee was appointed to study the question of the quality of transmission. The first meeting of this sub-committee was held in London from December 5th-10th, and was attended by about 28 delegates from Chile, France, Germany, Great Britain, Holland, Japan, Mexico, Sweden and U.S.A.

The question of quality rather than volume alone has become of paramount importance now that the attenuation of lines can be eliminated by the use of amplifiers. In many ways also it is now possible to improve the quality, e.g., by transmitting a greater range of frequencies, by improvements in the transmitter and receiver, by the reduction of the sidetone, etc. Up to the present the transmission between two telephones has been measured in terms of the simple attenuation which has to be inserted between two standard telephones to make the volume of sound received appear equal to that of the circuit under test. The quality was indicated by separate articulation tests.

As an example of the improvements available, the new Post Office receiver No. 2P will give transmission equal to or better than the old receiver No. 1L, over an attenuation greater by from 2 to 9 db. according to the conditions of noise, etc., although the volume efficiency of the two receivers is approximately equal.

As long as there was little change in the articulation it was not necessary to make any definite allowance for changes in quality. Large improvements are now possible and if advantage of these is to be taken in planning transmission layouts, some method of obtaining a single value which will express the combined effect of all the factors is necessary. It is very desirable that international agreement should be reached so that all international transmission can be planned on the same lines.

Owing to the varying effects of noise and sidetone on the subscriber himself and of other variable factors such as the method of holding the telephone, it has been found that the old methods of making tests in the laboratory are unsatisfactory. It was agreed at the meeting that whatever methods are finally adopted the result must include the effects of the subscriber's reactions.

It was also agreed that the best criterion so far known of the subscriber's reactions, is the rate at which repetitions are necessary in a conversation. It is, however, obviously not possible to make ordinary transmission measurements by counting repetitions; some other test must be used and the results adjusted to agree with those which would be found under working conditions.

A number of proposals with this object in view were made, chiefly by America and this country. It was decided on an American suggestion that a series of tests based on articulation should be made by the S.F.E.R.T. laboratory, on telephones and circuits from various administrations, in particular from America. The Bell Laboratories have made an extensive series of repetition rate tests on their systems, and also offered to make further tests on European telephones. The S.F.E.R.T. tests will enable effective transmission values to be computed from the results by the different methods of articulation tests proposed and compared with the repetition rate values. They will be made in such a way that, even if exact correlation is not obtained, the results will be much nearer the real effective transmission ratings for the various systems than are the volume ratings now in use, and will form a first step towards putting European telephone transmission on an effective basis.

Some consideration was also given by the committee to objective tests of telephone instruments. A small sub-committee laid down the essential requirements for articulation tests, and another sub-committee considered the question of the noises which should be used for such tests in order to simulate working conditions.

This sub-committee was presided over by Capt. Cohen, of the Research Branch, who retired in December, and suitable tributes were paid to him by Mr. Frank Gill and Monsieur Valensi.

Sub-Committee for Questions Concerning Wide-Band Transmission.

The 3rd Commission of Rapporteurs of the C.C.I.F., at the meeting in Stockholm, in 1934, agreed the fundamental characteristics of carrier systems, providing one carrier circuit in addition to the voice circuit, for international circuits in loaded underground cables, and at the meeting in London in 1936 carrier systems providing up to three carrier circuits in addition to the voice circuit, were dealt with. At the latter meeting, besides agreeing to study the question of multi-circuit carrier on non-loaded cables, administrations undertook to give consideration to questions concerning systems for wide-band transmission (such as the coaxial system) and questions concerning the transmission of television. These matters were discussed in June, 1938, at the meeting in Oslo and an agreement of far-reaching importance resulted, concerning the characteristics of multi-circuit carrier systems for non-loaded cables. In effect the frequency-allocation of the system known in this country as "12-circuit carrier" was standardised for international circuits, but with the important difference that upper sidebands are to be transmitted, not lower sidebands as in the systems in use by the Post Office at present.

Development had been proceeding with "upper sideband" in some countries and "lower sideband" in others, and agreement could only be reached by a concession which involved a change in direction in development work or the development of special terminal equipment for international circuits. There was a similar situation in regard to the width of frequency band to be allotted to each channel, and here also agreement was reached by material concessions.

The discussions at Oslo on wide-band systems afforded a valuable opportunity for interchange of information on coaxial systems, but it was clear that the time was not ripe for agreement beyond making the first step towards the formulation of an international frequency allocation. It was agreed that the group of 12 channels spaced at 4 kc/s, standardised for non-loaded cable, should form the starting point for any internationally agreed allocation and that such an allocation should be suited to derivation from groups assembled between 12 and 60 kc/s (upper sidebands), and assembled from groups between 60 and 108 kc/s (lower sidebands—for systems employing crystal filters).

With the hard-won agreement as to 12-circuit carrier systems in mind it was decided that a sub-committee should meet in London in December, and questions were formulated chiefly with a view to arriving at an agreed frequency-allocation. It was evident that, if the matter was left in abeyance until the meeting in Lisbon in 1940, development in coaxial systems might diverge with the result that agreement might then be possible only at the cost of serious concessions involving recasting of otherwise entirely satisfactory designs of equipment. In addition to this matter, questions concerning carrier systems for loaded cables were remitted to the sub-committee which was also asked to consider specifying the characteristics of international circuits for television.

The sub-committee was addressed by Sir George Lee at its opening meeting on December 12th, 1938, who, after welcoming the delegates, spoke of the importance of the sub-committee's work, referring particularly to systems of wide-band telephony, and wished success to the conference. The sub-committee comprised 58 representatives of Argentine, Cuba, France, Germany, Great Britain, Holland, Italy, Japan, Mexico, Rumania, U.S.A. and Uruguay.

Frequency Allocation.—Question No. 1 bis (concerning the characteristics of wide-band systems of telephony) was considered first. A series of propositions of a general nature, formulated in the light of the replies received from the various administrations, formed the basis of a discussion which revealed not only the points upon which there was disagreement but also the considerable field in which the conference was in agreement. Several frequency allocations were proposed and discussed, with the blackboard in constant use. The crucial points by which each proposed allocation was tested, were—

(*a*) ease of generation of the carrier frequencies required for transfer of groups to the basic super-group positions, and transfer of super-groups from the basic to their final positions in the frequency spectrum; (*b*) the suitability of the allocation for building up from the two basic 12-channel groups recognised at Oslo, viz., 12-60 kc/s (upper sidebands) and 60-108 kc/s (lower sidebands); and (*c*) the suitability of the allocation for building up from the two basic groups without using super-groups as an intermediate step. These points will perhaps be more clearly appreciated by consideration of the frequency allocation finally adopted by the sub-committee for recommendation to the 3rd C.R.

The frequency allocation finally agreed is a modification of one described at Oslo by Dr. Osborne, of the American Telephone and Telegraph Corporation. In the discussions and expositions leading up to acceptance of the single frequency allocation for all systems, the most prominent participants were perhaps Professor Küpfmüller (Germany and Uruguay), Dr. Mayer (Germany), and Messrs. Stanesby and Halsey (Great Britain), Mr. Halsey suggesting the allocation which enabled unanimity to be reached.

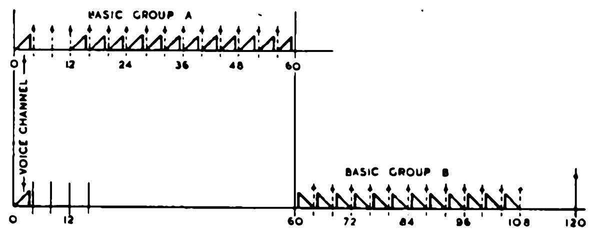


FIG. 1.

Fig. 1 indicates diagrammatically the position of channels in the two basic groups designated A and B. Where channels are assembled in position B (using crystal filters) modulation of the group as a whole with a carrier frequency of 120 kc/s and subsequent selection of the lower side-band brings the group into position A corresponding to the frequency allocation agreed for international 12-circuit carrier. This indicates the relationship of the two basic group positions.

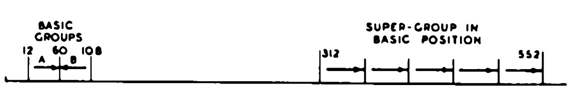


FIG. 2.

Fig. 2, at the left, shows the two basic groups according to the convention provisionally adopted by the conference. The directions of the arrows represent channels with the order of frequencies erect and inverted in the groups A and B respectively. Nine super-groups, comprising 5 groups, is shown in the basic position on the right. Each arrow represents 12 channels and from their direction it will be seen that a frequency inversion is involved in passing from group B to the basic position of the super-group, but not when the super-group is derived from the basic group A.

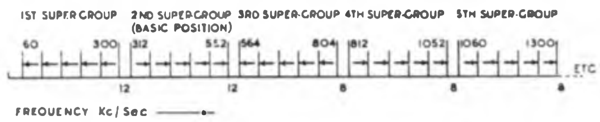


Fig. 3

Fig. 3 shows the positions of super-groups in the agreed frequency allocation. Gaps of 12 kc/s are left unused on either side of the super-group occupying the basic position between 312-552 kc/s. Between all other super-groups the gaps are only 8 kc/s. This non-uniformity in the size of the gaps is attributable to the omission of any further modulation of the super-group in the 2nd position after assembly in the basic position, and to the derivation of the super-group modulating frequency of the first super-group from the harmonic series from which the group modulating frequencies are derived.

Starting with basic group B the group modulating frequencies are 420, 468, 516, 564, 612, i.e., 35th, 39th, 43rd, 47th, 51st harmonic of 12 kc/s.

To translate a super-group from the basic position to that of the 1st super-group a modulating frequency of 612 kc/s is required. This would be obtained as the 51st harmonic of 12 kc/s. The modulating frequencies for translation to the 3rd and higher positions are 1364, 1612 . . . etc. kc/s. These are the 11th, 13th . . . etc., harmonics of 124 kc/s. In all these modulations the lower sidebands are selected, accompanied by a frequency inversion.

Where basic group A is used the upper sideband is selected in the modulations which translate the groups to their positions in the basic super-group position. The carrier frequencies are the 25th, 29th, 33rd, 37th, 41st harmonics of 12 kc/s. The modulations from the basic super-group position are of course unaffected by the choice of basic group.

In recommending this frequency allocation the conference envisaged that in some systems all the groups shown at the lower end of Fig. 3 might not be transmitted, while the highest frequency transmitted would vary with the number of groups of channels transmitted. But whatever the number of groups to be transmitted it has been recommended that those transmitted should conform with the relevant part of Fig. 3.

The frequency allocation recommended is suited to the direct transfer of groups from their basic position A to their positions in the 1st and succeeding "super-group" positions without a super-group modulation.

The recommendations of the sub-committee in regard to the frequency allocation for wide-band systems for telephony have been described at some length because of their importance and great interest. If the remainder of the work of the conference is passed over somewhat lightly, it is due to lack of space rather than to any under-estimate of its importance.

General.—At Oslo it had been agreed that the individual channels of 12-circuit and other systems for non-loaded cables (including coaxial systems) should transmit effectively audio frequencies from 300 to 3,400 c/s. The amplification of this requirement was remitted to the sub-committee and the recommendation made is that international 4-wire circuits in terminal service designed to transmit frequencies between these limits shall be in accordance with Fig. 4, which shows permissible limits of variation from the transmission equivalent at 800 c/s.

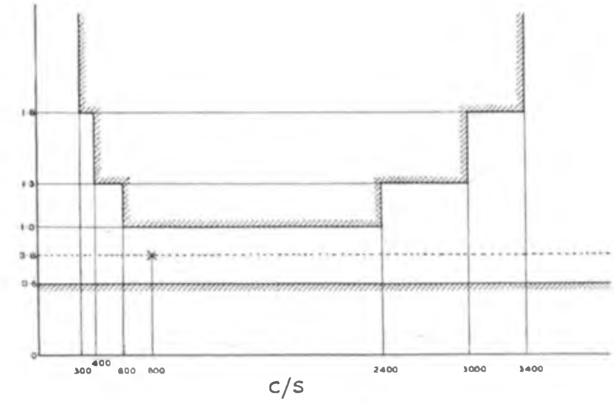


Fig. 4

Questions concerning carrier circuits on loaded cables were dealt with, and a number of limits for crosstalk harmonic distortion, etc., have been added to the existing recommendations. Useful discussions took place concerning measurement of harmonic distortion in negative feed-back repeaters, and a suggested definition of maximum useful power was recommended for examination by administrations.

In addition to the work of the conference on questions particularly concerning wide-band transmission, a special sub-committee of members of the conference held meetings under the able chairmanship of Professor Küpfmüller to consider modified definitions of terms relating to reflections and electrical echoes. Owing to the great interest of all the members of this sub-committee in the main work of the conference its meetings were held before the commencement of the main session on a number of days, the members participating thus increasing the length of their already arduous sessions. The special sub-committee covered the ground allotted to them but insufficient time was available to come to full agreement, and modified definitions have been recommended for further study.

Television transmission was discussed by the conference but while realising the importance of any lead which the C.C.I.F. might be able to give in recommending limits for width of frequency band, allowable phase and attenuation distortion, etc., the conference, with some regret, came to the conclusion that this was not possible since there was no agreement as to the characteristics of systems for the generation and reception of television signals to be transmitted over international circuits. A joint meeting with delegates of the U. I.R. (Union Internationale de Radiodiffusion) showed that this view was shared by the U.I.R. M. Braillard's reply to the chairman's welcome to the U.I.R. will long remain a pleasant memory to those who were present. M. Van der Pol (Holland) gave expression to the trend towards the definition of characteristics of television circuits in terms of response to impulses rather than in terms of the usual "steady state" language of the telephone transmission engineer.

During the course of the discussion a questionnaire formulated by the German delegation, was considered and with some modifications this was adopted and will replace the question originally formulated for discussion at Oslo. In its new form it comprises 13 parts which define characteristics of television circuits, for which limits should be specified. The further study of the question in preparation for the meeting in Lisbon will be helped by the greater explicitness of the question.

At the closing session on December 17th Dr. Düll (Germany), on behalf of the members of the sub-committee expressed their thanks for their welcome to London and the arrangements made for their comfort, and paid a well-deserved tribute to M. Valensi, Secretary General of the C.C.I.F.

The feeling at the conclusion of the conference was that the results obtained, especially in the work of wide-band systems, fully justified the calling of the meeting.

Social Arrangements during the Meetings.

Visits were arranged for the delegates to the Research Station, Dollis Hill, and also to Faraday Building, where demonstration calls over the London-Birmingham coaxial cable were made. In addition, the B.B.C. arranged a visit to Alexandra Palace, where the delegates were taken over the studios and the sound and vision transmitting rooms during an actual transmission.

The delegates also attended the official banquet at the Savoy Hotel, on December 8th, 1938, presided over by Sir George Lee, the Engineer-in-Chief, who proposed the toast of "Rulers and Heads of Sovereign States and Nations." A very enjoyable evening was spent renewing old acquaintances and making new ones.

A banquet and entertainment given by the telephone manufacturers of Great Britain was extended to the delegates and their ladies. This was attended by about 250 guests. The toast of the C.C.I.F. was proposed by Mr. F. Gill, and the response was made by Professor Küpfmüller.

Book Reviews

"Electric Lifts." R. S. Phillips, A.M.I.E.E. 293 pp. 191 ill. Pitman. 20s.

The author was awarded a bronze medal for his paper on modern electric passenger lifts, read before the I.P.O.E.E. in 1935, and the idea of the book originated as a result of discussion on the paper which brought to prominent notice the need for an up-to-date authoritative book on British lift practice. Actually, the last book on this subject published in this country was written in 1923, although there are several books dealing exclusively with American practice. There is, of course, a large amount of information available in various periodicals and manufacturers' publications, but this matter is not generally available and the present book brings the information together in convenient form. The lack of standardisation in lift practice is well illustrated by the various manufacturers' products and methods described and illustrated and the author must have experienced difficulty in deciding what to leave out to keep the book within reasonable dimensions.

The lift specialist will find little new in the book and will have no difficulty in finding arguments for or against the various alternatives adopted by different lift makers, but, on the whole, the methods described are representative of good lift practice and apply to lifts having speeds usual in this country. It is noted that the author quotes an angle of 42° as that recommended by B.S.S.329—the angle has recently been amended to 35°—and also no mention is made of the danger attending the use of car floor switches which cut out the car gate contact.

The book is well illustrated and there are numerous wiring diagrams of various types of controllers. The chapter on maintenance and testing could, with advantage, have been in much more detail. The problem of interference with wireless reception due to electric lifts is dealt with in an appendix. W. T. G.

"The Nomogram—The Theory and Practical Construction of Computation Charts." H. J. Allcock, M.Sc., M.I.E.E., A.M.I.Mech.E., Mem.A.I.E.E., and J. R. Jones, M.A., F.G.S. 224 pp. 77 ill. Pitman. Second Edition. 10s. 6d.

This reasonably priced book provides one of the most complete treatises on the subject of nomography published in England, and will prove of use not only to the engineer, but to the mathematical student. The second edition has information regarding circular nomograms, but otherwise it differs little from the first.

As the authors point out, ignorance of the application of nomograms has resulted in their neglect by engineers, but a study of this book will show that alignment charts, once constructed, can be of more value than the slide rule where repeated calculations are made from the same formula.

Readers of the book should have a thorough understanding of the analytical geometry of linear equations and the elementary theory and manipulation of determinants, although a few pages are devoted to the latter in the book. Nomograms for formulae involving as many as four variables are discussed in great detail, and the non-mathematical student will tend to be overawed by this wealth of detail regarding the theory underlying each constructional step, whereas he is only interested in the method. A useful summary, however, in the form of an appendix will considerably assist him in nomogram construction after a first reading. The concluding pages are devoted to an indication of the methods for constructing charts having a greater number of variables.

The style of the book is pleasing and makes for easy reading, but to some the frequent use of "obviously" and kindred expressions will prove exasperating.

E. H.

The Universal Decimal Classification of Information

U.D.C. 025.45

J. E. WRIGHT

A description is given of the Universal Decimal System for the classification of information. This is the only system in world-wide use for the classification of technical information and has been adopted to classify the articles appearing in this Journal.

Introduction.

MANY schemes have been devised for classifying books and knowledge. Alphabetical arrangements have always been popular and for certain purposes they are indispensable, but many attempts have been made to divide knowledge into groups having a numerical coding. The use of arabic numbers has always been recognised as advantageous because the numbers themselves constitute an international language. A classification into groups of ten is bound to follow unless repetition of the numbers is to be permitted. In these ideas can be seen the seeds of a decimal classification and in 1876 the famous decimal classification of Melvil Dewey was produced.

About this time librarians and others concerned with indexing began to wake up to the fact that some scheme of indexing capable of adoption throughout the world was necessary. The first International Bibliographical Conference was held in 1895 and it was then decided that the Dewey Decimal Classification should be the basis of a system of indexing suitable for classifying the published literature of the world.

The Universal Decimal System.

A universal classification system should fulfil certain conditions. The system should be founded on some logical division of knowledge and it should be designed to permit unlimited expansion to be made. Language differences should not affect the application of the system. It must be governed by rules to ensure uniformity of practice but it should be easily workable and free from complications. The Universal Decimal Classification can be said to meet these requirements. Developments arising with the passage of time, particularly in science and engineering, have necessitated very considerable expansion of the divisions of certain subjects. It may be thought, as a result, that undue importance has been given to certain subjects in comparison with others. Nevertheless if the process of subdivision is studied it will be clear that a logical basis does exist. Clear and definite rules have been established and a permanent commission and secretariat, guided by international subject secretariats, give final decisions regarding amendments and extensions.

The Universal Decimal Classification system of indexing is now used very extensively by libraries and information bureaux, and of recent years an increasing number of publishers of scientific periodicals have classified their articles by this system. Unless some attempt is made to discover the principles of the U.D.C. the numbers at the head of these articles are completely meaningless. The numbering is a code and its key is the U.D.C. tables.

The tables of the U.D.C. have been produced by dividing all knowledge into ten classes and by continuing to sub-divide those classes and their sub-divisions by ten until sufficiently detailed sub-divisions have been obtained. The ten main classes that have been chosen are shown in Fig 1. The method of dividing these divisions by ten can be seen. It will be appreciated that an extensive division of any one subject has no disturbing effect on the system. The extent to which sub-division may be necessary can be seen from the following :—

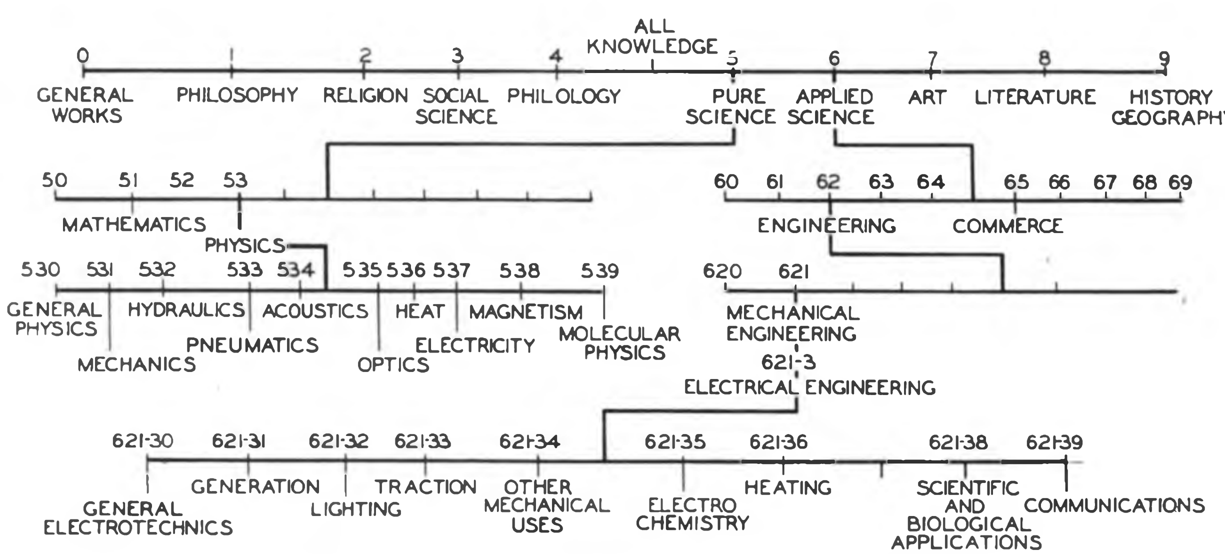


FIG. 1.—MAIN STRUCTURE OF THE UNIVERSAL DECIMAL SYSTEM.

6	Applied Science
62	Engineering
621	Mechanical engineering
621.3	Electrical engineering
621.39	Electrical communications engineering
621.395	Telephony by wire
621.395.6	Telephone apparatus
621.395.64	Amplifiers
621.395.645	Valve amplifiers
621.395.645.3	Valve amplifiers using feedback
621.395.645.34	Valve amplifiers using negative feedback

If each of the main classes were assumed to have the same number of sub-divisions as this example from class 6 there would be something like 10^{11} divisions. This is not the case but there are certainly millions of sub-divisions of the U.D.C. tables in use to-day.

For convenience of reading it is usual to insert a stop after every third figure in the same way that a comma is inserted to assist us to check up the noughts in £10,000,000.

Certain articles, although written about only one subject, require to be indexed from more than one point of view; for instance, "the corrosion of telephone transmitters." The classification number for "corrosion" is 620.19 and the number for the division for "telephone transmitters" is 621.395.61. To indicate the nature of this article the two numbers are associated with each other by means of a colon sign, thus, 620.19 : 621.395.61. Should an article need to be classified from two points of view that are not associated, as, for instance, "telegraphy and telephony," the respective numbers would be shown separately, usually one under the other, or sometimes 621.394 + 621.395. Cross-references are very necessary if an index is to be a good one. With the two examples given, cross references can be obtained by the simple process of re-arranging the order of the numbers, thus :— 621.395.61 : 620.19 instead of 620.19 : 621.395.61 and 621.395 + 621.394 instead of 621.394 + 621.395.

Auxiliary Classification.

The U.D.C. tables produced by repeated division by ten are sufficient for many indexing requirements. Some very specialised indexes, however, must be classified in greater detail. "Analytical" and "auxiliary" tables have been prepared for these requirements. These tables cover particular points of view such as considerations of economics, time, place. Their index number may be added to a number from the main tables. In practice, the inclusion of the analytical classification number which is used to indicate the technical view point is generally sufficient for indexing matter relating to electrical engineering. The extent to which it is possible to apply the U.D.C. tables is indicated in the table below, but it is important to realise that the use of the analytical and auxiliary sections of the tables should be restricted to a minimum necessary for the type of index for which the references are being made. Auxiliary tables will seldom be required for an engineering index.

Tables.

The full tables of the U.D.C. appeared as a complete French edition in 1933 and parts of the tables of the German and the English editions are already in the press. These editions will be translations of the French edition brought up to date by the inclusion of the amendments and additions to the tables that have received approval since the 1933 edition was published. In the meantime an excellent abridged set of tables has been produced by the staff of the Science Library and published by His Majesty's Stationery Office at five shillings. The Post Office Engineering Department Research Report No. 10040 gives full U.D.C. tables of the subjects related to electrical communications. At present this is only available to those who are normally entitled to Departmental Research Reports but there is no doubt that a demand exists in this country for an English edition of the U.D.C. tables.

An alphabetical subject key is associated with the U.D.C. tables and this should be used as a guide to the relevant sections of the tables when a subject is to be referred to. Abstracts and references classified by the U.D.C. notation are filed in the numerical order of the U.D.C. numbers so that once the proper division number of a line of enquiry has been established the information should be readily found.

Conclusion.

The Board of Editors has decided to adopt the Universal Decimal System to classify the articles in this Journal in order to assist librarians or those readers who find it convenient to maintain more elaborate indexes than the alphabetical indexes issued with each volume and periodically to cover longer periods.

It is not possible to give here the whole of the

TABLE.

621.395.645.34	029.63	.003	(43)	" 1937 "	(043)	= 3
Subject division	Technical viewpoint	General viewpoint	Place	Time	Form	Language
Main table	Analytical table	Auxiliary tables				

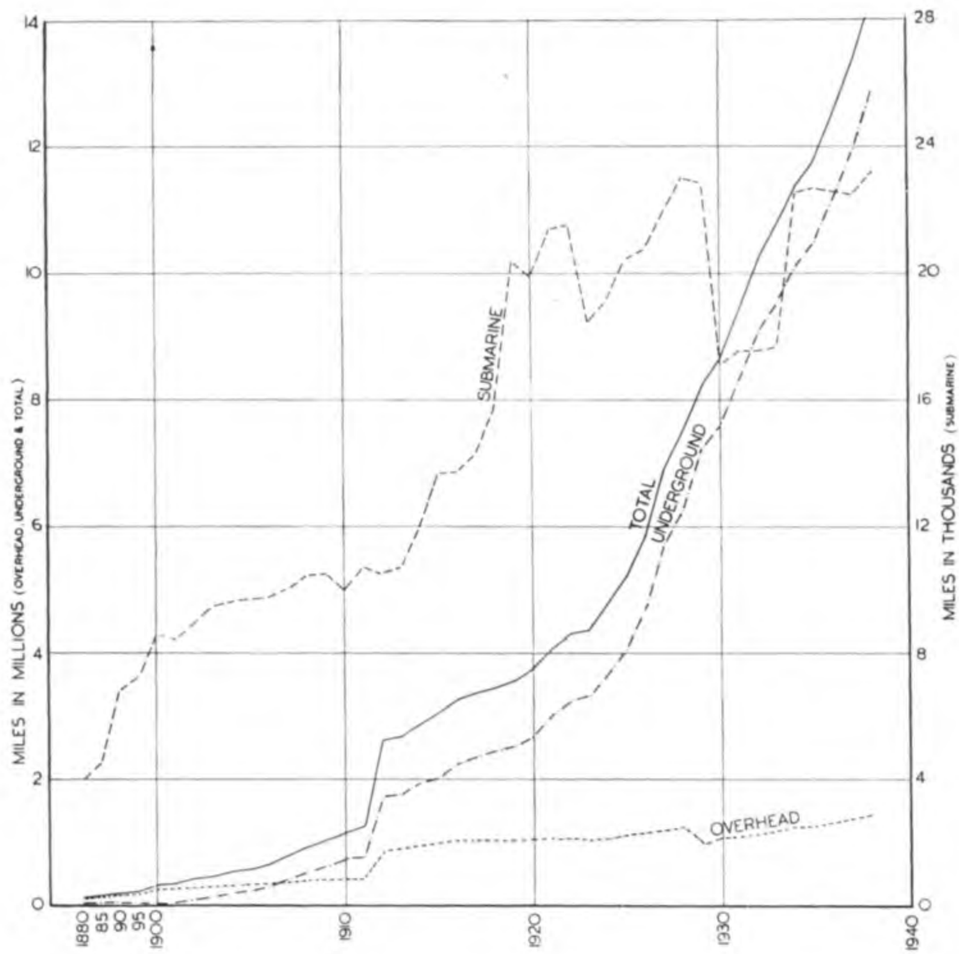
This number is interpreted.

621.395.645.34	Amplifier with negative feedback
029.63	For decimetre wavelength
.003	From the point of view of economics
(43)	In Germany
" 1937 "	In 1937
(043)	A dissertation
= 3	In German.

sub-divisions of the U.D.C. tables that will be used for classifying the articles appearing in this journal. The classification numbers used will, however, be further sub-divisions of the following :—

51	Mathematics
53	Physics
534	Acoustics
537	Electricity
538	Magnetism and Electromagnetism
621.314	Transformation of electrical energy
621.315	Transmission of electrical energy
621.316	Distribution and regulation of power
621.317	Electrical measurements
621.318	Applied magnetism
621.319	Applied electrostatics
621.35	Industrial electrochemistry. Cells. Accumulators. Plating.
621.383	Photo-electricity. Photo-electric cells.
621.385	Thermionic valves. Electronic discharge apparatus.
621.391	General considerations of electrical communications.
621.394	Telegraphy by wire
621.395	Telephony by wires
621.396	Radio communication
621.397	Transmission of pictures
654.1	Commercial aspect of telegraphy, telephony and radio.
66	Industrial chemistry
669	Metallurgy
67	Various industries and manufactures.

Total Single Wire Mileage for all Services



The Pendant Telephone

U.D.C. 621.395.623.63 621.395.721.1

J. D. HINCHCLIFF

The Author describes the new Pendant Telephone and Dialling Unit which was made available to the public on the 1st March, 1939.

Introduction.

ARTISTIC appearance and convenience to the user are important factors in the design of any telephone instrument. Many business executives prefer to have their tables free from obstructions and in some situations, such as stock exchanges and hotel lifts, space economy is very desirable. To meet such needs a new telephone instrument described as the pendant telephone and an associated dialling unit have been designed in collaboration with the Plessey Co., Ltd., and have been coded as "Telephone No. 246, Black," and "Mounting Dial Auto No. 16" respectively. The unit has been favourably commented upon when fitted for trial to the service lines of certain higher Post Office officials.

Primarily the telephone was designed for use in desk knee-holes, a typical installation when not in use being illustrated in Fig. **1**, whereas Fig. **2** shows a different installation ready for establishing a call. The telephone itself may be used without the dialling unit at non-dialling stations where a compact wall instrument is required, but its use in this manner on direct exchange lines in manual areas is not encouraged in view of the ultimate conversion to automatic working. This instrument is subject to a special charge and is at present only supplied in black, but may be introduced in the standard colours later if demands justify this course.

Fig. 1.—Typical Installation.

Fig. 2.—Telephone and Dialling Unit Ready for Use.

Telephone.

Essentially the telephone comprises a standard handset together with a switch-hook bracket moulded in bakelite with a metal backplate. The instrument is used in conjunction with a separate bell set incorporating the induction coil, and this arrangement, together with the provision of sufficient contacts on the switch-hook spring set enables the one type of pendant telephone to be used on all systems. The bell set may be accommodated in any unobtrusive position to the requirements of the subscriber. Some novelties in the general design include the use of an extensible handset cord and the general adoption of rubber sleeves at the cord entry holes in the telephone where hitherto the majority of cord faults has occurred.

Fig. **3** illustrates the inside of the telephone and the backplate used for fixing the instrument direct to an upright or to the table-mounting bracket. This bracket, coded as "Bracket Mounting B.U." is reversible for a left- or right-handed fixing, but normally the telephone should be to the left and the dialling unit to the right of the user. The internal connections are all accessible and brought out to separate terminals which are in turn wired through a cord to a terminal block for connection to the external wiring. Because of the alternative methods of

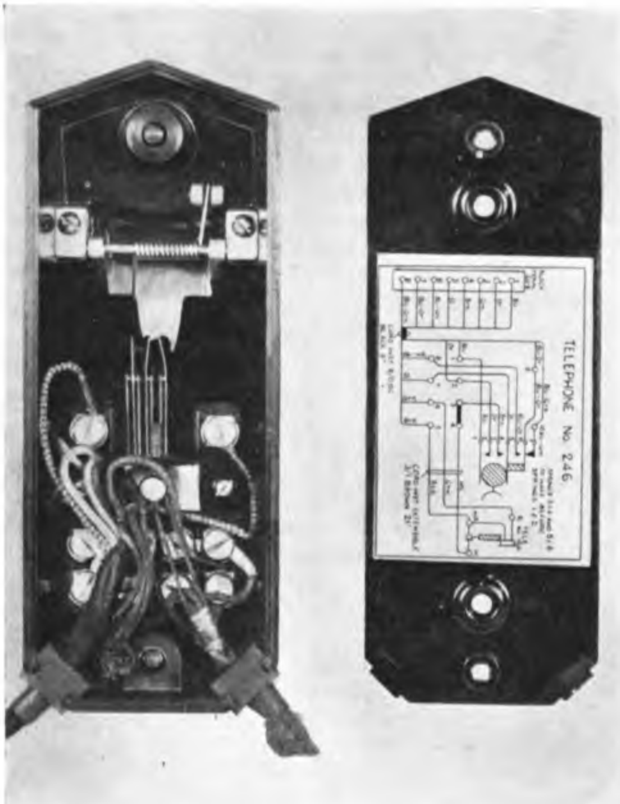


Fig. 3.—Interior of the Telephone.

mounting the telephone previously mentioned, the positions at which the two cords are brought out of the instrument body are interchangeable, so that the handset cord is at the side adjacent to the user in any particular installation.

Cords.

The requirements governing the choice of the handset cord length are somewhat conflicting, as it is essential to have the standard length of **42** in. when the telephone is in use, and yet when normal the cord must be short enough to clear the floor. It was finally decided to adopt an extensible cord having a normal length of **21** in. and capable of extension to **42** in. This cord incorporates the usual tinsel-plaited conductors, which extend and collapse round a central elastic core. Other types of extensible cords have been and are under test, but that at present adopted appears to be the most promising, and its introduction on the pendant telephone affords an opportunity for a valuable service trial.

Dialling Unit.

The dialling unit, which is of the drawer type, has three main components : a moulded bakelite mounting for the dial, a cadmium-plated metal slide housing the mounting and an eight-way terminal block. The underside of the unit is illustrated in Fig. **4**, where the long trapped securing screw for the dial, and the bakelite dust cover and securing ring have been specially shown. The cord which connects the dial to the terminal block is secured by the two insulating clamps indicated. This cord must have great flexibility and endurance, and consequently cordage similar to that used for switchboard cords was chosen and, in spite of the large conductor cross-section, the manufacturers were able to provide the usual bound loops, small enough to fit the 8 B.A. terminal screws on the dial.

In order to ensure a smooth, pleasing action when withdrawing the mounting for use, the slide has been lined with felt, and to secure rigidity when fully withdrawn, the cross-bar indicated in Fig. **4** registers in the slots in the mounting side. A special bracket coded as " Bracket Mounting B.V." has been designed to support the dialling unit where direct fixing is impracticable, and this bracket may be used for left- or right-hand fixing as with the telephone supporting bracket.

Fitting.

When installing a pendant telephone the brackets mentioned above may be used where direct fitting of either component of the installation is impracticable, and a number of alternative fixing holes has been provided to ensure a satisfactory fixing. The alternative mounting for the telephone shown in Fig. **2** has been obtained by using the appropriate bracket.

A further novel feature is the introduction of a schedule of stores required for any particular installation, shown on the first panel of each installation wiring diagram for the instrument. It is hoped that these schedules will be of service to the fitting staffs concerned.

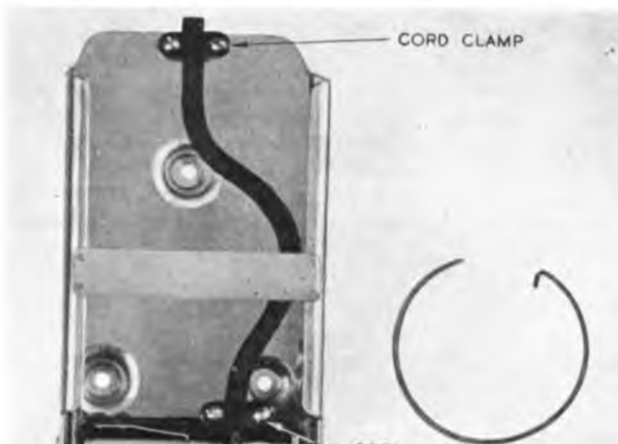


Fig. 4.—Underside of the Dialling Unit.

Note on the Resistance Noise in a Coaxial Pair

U.D.C. 537.311.1 : 621.315.212

H. J. JOSEPHS, A.M.I.E.E.

This note contains a simple formula for the calculation of the magnitude of the thermal noise voltage arising in a coaxial pair. The formula can be used to predict the limit of noise reduction in a coaxial transmission line.

General.

An alternating voltage can always be amplified provided it is large enough to mask the small noises in the input circuit of a high-gain amplifier. Some of these noises, for example, those due to vibration, induction, microphonic effects, poor connections and insulation, etc., can be eliminated ; but other noises are inherent and cannot be eliminated. It is these inherent noises which determine the limit to the amount of amplification that can be usefully employed. The fundamental sources of noise are :

(*a*) Noise due to voltage fluctuations within the valves of the amplifier ;

(*b*) Noise due to the thermal agitation of electricity (resistance noise) in the input circuit of the first stage of the amplifier.

If the impedance of the input circuit is high, then the noise arising from (*a*) will be small compared with the noise arising from (*b*). It is desirable, therefore, to design the input circuit to have a high impedance, because, for a given input power, the largest signal-to-noise ratio is obtained. Thus, if small signals received at the end of a low impedance coaxial pair are to be amplified, it will be necessary to connect the pair to the amplifier by a transformer to ensure that the input impedance of the amplifier will be effectively high. The input transformer should be designed to close the coaxial pair with its characteristic impedance ; also, to obtain a high voltage step-up at the highest frequency to be transmitted (and thus allow the input signal to over-ride the valve noises) a screened-grid valve having a low input capacity should be chosen for the first stage of the amplifier. A termination designed on these lines gives the highest signal-to-noise ratio, has negligible reflection loss and allows the amplification to be limited only by the magnitude of the thermal noise voltage which arises in the coaxial pair itself. It would be useful therefore, to have a simple formula to predict the thermal noise voltage in a correctly terminated coaxial pair. In the Appendix it is shown that the average thermal noise voltage $\overline{E}$ that arises in a correctly terminated coaxial pair with a solid core, is given by the formula,

$$\overline{E} = \sqrt{8\,v\,K\,T\sqrt{\frac{\mu}{\epsilon}}\,(f_2 - f_1)\log_e\frac{b}{c} \times 10^{-9}} \quad \ldots\ldots (4)$$

where

f_2 = highest frequency to be transmitted.
f_1 = lowest frequency to be transmitted.
μ = permeability of dielectric.
ϵ = dielectric constant.
c = radius of core in cms.
b = internal radius of sheath in cms.

v is the velocity of light (3×10^{10}) ; K is Boltzmann's constant ($1{\cdot}37 \times 10^{-23}$) watt second per degree ; and T is the absolute temperature in degrees. $\overline{E}$ is in volts.

Consider a coaxial pair with a solid core ; let the internal diameter of the sheath be 1·143 cms. and the diameter of the core be 0·3175 cms. If the pair is at a temperature of 27° C. and the width of the frequency transmission band is 3 megacycles per second, then, according to equation (4), the thermal noise voltage will be of the order of 2 microvolts. Assuming that the lowest winter temperature is −3° C. and that the highest summer temperature is 32° C., the change in the thermal noise voltage between winter and summer temperatures is only 0·08 microvolt. The formula also shows that the minimum power due to thermal agitation is $1{\cdot}64 \times 10^{-20}$ watts per cycle. The variation of this power with temperature is so small that it may be neglected. Consequently the thermal noise power at the input of an amplifier terminating a coaxial pair depends for all practical purposes only on the width of the frequency band within which the amplification is appreciable. Because of the random character of the thermal noise energy, its instantaneous wave shape is unknown, and consequently it can only be specified by its statistical frequency distribution. Thus the solution of the general problem of thermal noise calls for the methods of mathematical statistics.

Appendix.

Consider a coaxial pair at the same temperature throughout and closed at the ends by its characteristic impedance. Then the elemental power during the frequency interval df is $d(\overline{E})^2/2R(f)$, where $(\overline{E})^2$ is the mean square thermal agitation voltage and R(f) is the resistance of the source producing this voltage at the frequency f. From the principle of the equipartition of energy in a coaxial pair this elemental power may be written 2 K T df, where K is Boltzmann's constant and T is the absolute temperature. Thus

$$\overline{E} = \sqrt{\int_F 4\,K\,T\,R(f)\,df} \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

where F is the frequency band width in cycles per second. This expression is due to H. Nyquist and will be found in *The Physical Review* for July, 1928.

The function R(f) which appears in equation (1) may be formulated from the theory of the coaxial cable. Suppose the coaxial pair consists of a hollow cylinder or sheath of external radius a, internal radius b, surrounding a solid core of radius c. Let L_0 and C_0 represent the inductance and capacitance of the annular space. Let R_s and L_s denote the effective resistance and inductance of the sheath, and let R_c and L_c denote the same quantities for the core. Neglecting the small leakage in the annular space, the resistive component of the characteristic impedance is given by

$$R(f) = \sqrt{\frac{L}{2C_0}\left\{1 + \sqrt{1 + \left(\frac{R_c + R_s}{\omega L}\right)^2}\right\}} \quad \ldots\ldots (2)$$

R(f) is a continuous finite function of the frequency which converges to zero at infinity and is everywhere positive. It possesses no sharp maxima or minima and its variation with respect to frequency, where it exists, is very slow, and consequently the mid-point of the frequency scale can be used for the purpose of integration. Substituting (2) in equation (1) and performing the indicated operation,

$$\overline{E} = \sqrt{2\sqrt{2}\,K\,T\,(f_2 - f_1)\sqrt{\frac{L_o}{C_o}}(X + \sqrt{X^2 + Y^2})} \quad \ldots (3)$$

where, in c.g.s. units,

$X = L/L_o$ and $Y = (R_c + R_s)/\omega_o L$

$L_s = -\rho\, m\, Z\,(mab)/2\pi b\, \omega_o\, V\,(mab)$

$L_c = \rho\, m\, Z\,(mc)/2\pi\, c\, \omega_o\, V\,(mc)$

$R_s = -\rho\, m\, W\,(mab)/2\pi\, b\, V\,(mab)$

$R_c = \rho\, m\, W\,(mc)/2\pi\, c\, V\,(mc)$

$m^2 = 4\pi\,\mu\omega_o/\rho$ and $\omega_o = \pi(f_2 - f_1)$.

ρ is the resistivity of the conductors in c.g.s. units.

$W\,(mab) = (A_r - B_r)(C_i - D_i) - (A_i - B_i)(C_r - D_r)$

$Z\,(mab) = (A_r - B_r)(C_r - D_r) + (A_i - B_i)(C_i - D_i)$

$V\,(mab) = (C_r - D_r)^2 + (C_i - D_i)^2$

A_r = ber mb ker′ ma — bei mb kei′ ma

A_i = bei mb ker′ ma + ber mb kei′ ma

B_r = ber′ ma ker mb — bei′ ma kei mb

B_i = bei′ ma ker mb + ber′ ma kei mb

C_r = ber′ mb ker′ ma — bei′ mb kei′ ma

C_i = bei′ mb ker′ ma + ber′ mb kei′ ma

D_r = ber′ ma ker′ mb — bei′ ma kei′ mb

D_i = bei′ ma ker′ mb + ber′ ma kei′ mb

W (mc) = ber mc bei′ mc — bei mc ber′ mc

Z (mc) = ber mc ber′ mc + bei mc bei′ mc

V (mc) = $(\text{ber}'\ mc)^2 + (\text{bei}'\ mc)^2$

If f_1 the lowest frequency to be transmitted is greater than 10 kc.p.s., then equation (3) reduces to

$$\overline{E} = \sqrt{8\,v\,K\,T\sqrt{\frac{\mu}{\epsilon}}\,(f_2 - f_1)\log_e\frac{b}{c} \times 10^{-9}} \quad \ldots (4)$$

which is the average value of the thermal noise voltage.

Book Reviews

"The Amateur Radio Handbook." Published by the Incorporated Radio Society of Great Britain. 300 pp. 2s. 6d., overseas 3s. 6d.

This is the first edition of a work published by the Incorporated Radio Society of Great Britain. The handbook, which is the joint effort of a band of enthusiastic amateurs, has been written primarily for amateurs, and is concerned with practical experience rather than with pure theory.

All the aspects of the subject from the view point of the amateur are considered in the twenty-five chapters. These include chapters on the design, construction and operation of low power transmitters and of receivers, aerials, television, frequency measurements, measuring instruments, station planning, regulations concerning the issue of licences to radio amateurs and on the aims and purpose of the Society. Difficulty is invariably experienced in the production of a practical handbook suitable both for the technician and for the man with a limited technical knowledge. The several authors have overcome this trouble to some extent, although it is not possible to agree with all the quoted theories and conclusions. This is perhaps an advantage in view of the object of the work, for in the words of the edition, "Amateur Radio would lose most of its charm if no challenger was at hand to refute another's opinion." The multiplicity of authors is unfortunately reflected in the different styles of the various chapters.

Despite these criticisms the handbook is strongly recommended to the attention of the radio amateur. The book represents good value for money and the Incorporated Radio Society of Great Britain is to be congratulated on the production of the first edition.

C. F. B.

"Automatic Telephony." Charles W. Wilman, M.I.E.E. 208 pp. 103 ill. The Technical Press, Ltd., 10s. 6d.

The second edition of Mr. Wilman's book on Automatic Telephony which has recently been published has been thoroughly revised and brought up to date. In the course of 200 pages the author gives a sound and comprehensive survey of the principles involved in the automatic selection of a number. No previous knowledge of automatic systems is assumed and the earlier chapters are, therefore, devoted to elementary trunking principles and to descriptions of the apparatus used. Although the B.P.O. standard system is principally described, other systems and alternative methods are mentioned freely.

The middle portion of the book deals with traffic, the various types of selectors (circuit elements only being given) and with multi-office areas. Finally, manual to auto and miscellaneous circuits, U.A.X.'s, party lines, etc., are briefly mentioned.

The book can be thoroughly recommended as an excellent introduction to the subject. From the Post Office engineer's viewpoint, however, the usefulness of the book is limited, as something more than basic principles is usually required, particularly for the City and Guilds of London Institute examinations. Even Grade I of Telephony requires the student to be able to draw circuit diagrams of 100-line group and final selectors, and necessitates knowledge of elementary trunking formulæ. None of this is included in sufficient detail in this work. Furthermore, equipment such as ballast resistors and traffic recorders receive scant mention and power plant is dismissed erroneously as being similar to manual practice. This, however, is one of the few mistakes noticed.

H. L.

Notes and Comments

News Year's Honours List

We offer our congratulations to those members of the Post Office staff who received awards in the New Year's Honours List. Chief among the recipients was Mr. W. R. Birchall, the Deputy Director General, whose distinguished services were fittingly marked by the accolade of knighthood. Among the Engineering Staff Mr. E. W. Knight, Assistant Engineer, South Midland District, became a Member of the Order of the British Empire and the following were awarded the Medal of the Order : F. W. Baker, S.W.1, Temple Bar Exchange ; J. H. F. Kellett, S.W.1, Chelmsford ; E. Rowland, S.W.2, North Midland District ; G. S. H. Tait, S.W.1, Edinburgh ; H. B. Taylor, S.W.2, Birmingham ; F. B. Wilcher, Inspector, Engineer-in-Chief's Office.

Recent Promotions and Appointments

We offer our congratulations to the following engineers upon their new appointments : Mr. J. Innes who is promoted to Acting Principal Assistant Secretary : Mr. C. A. Taylor, Mr. R. G. de Wardt, and Mr. A. Morris who are respectively appointed to Regional Director, Deputy Regional Director and Chief Regional Engineer, London Region ; Mr. J. J. McKichan who succeeds Mr. Taylor as Deputy Regional Director of the Scottish Region on May 1st, 1939, and on October 1st, 1939, is to become Regional Director of the new Midland Region ; Col. Carter who becomes Chief Regional Engineer, Scottish Region, in place of Mr. McKichan ; Mr. N. F. Cave-Browne-Cave who is the Deputy Regional Director designate of the Home Counties Region ; Mr. G. J. S. Little who is appointed as Chief Regional Engineer of the new North West Region : Mr. F. I. Ray and Mr. C. O. Horn who become Controllers, Telecommunications Branch, of the North West and Scottish Regions respectively.

Mr. L. Meek

It is with very great regret that his colleagues in the Engineering Department heard of the very sudden and unexpected death of Leonard Meek, which occurred on November 11th last.

Mr. Meek entered the service in 1912 as a transferred officer from the National Telephone Company, and after provincial experience was transferred to the Engineer-in-Chief's office in 1925 as a Chief Inspector. In 1930 he was promoted to the rank of Assistant Engineer in the London Engineering District, where he was responsible for a number of exchange transfers in the West and City sections. In 1936 he returned to the Engineer-in-Chief's staff to take charge as Executive Engineer of the Local Lines Group in the Transmission and Lines Branch. He was a contributor on several occasions to this Journal. His sterling qualities earned him the esteem and respect of his colleagues and friends to a high degree.

Universal Decimal Classification System

It has been decided by the Board of Editors that the articles in the JOURNAL commencing with this Part shall be prefixed by their Universal Decimal Classification number. An article describing the U.D.C. system appears in this issue and it is hoped that the classification will be of value to librarians and others who index the information appearing in the JOURNAL.

Binding

This issue is the first of volume 32 and in accordance with our practice, the colour of the cover has been changed. The reason for the change is to enable those of our readers who do not have their copies bound to distinguish readily the parts belonging to different volumes. Readers are reminded of the binding facilities which are available for previous volumes, full details of which will be found on page 78.

Portraits of the Great Men of Telecommunications

The Bureau de l'Union Internationale des Télécommunications publishes each year an engraving of a well known figure in telecommunications and has advised us that the portrait selected for 1938 is that of Marconi. A few copies of their previous publications, the portraits of Morse, Hughes and Bell, are still available.

These engravings are by well-known artists and the issue is limited to 600 copies printed on high quality paper 23 cm. × 18 cm. Copies can be obtained from the Union at Effingerstrasse No. 1, Berne, Switzerland, at a price of 2.50 Swiss francs per print, post and duty free.

Notes for the Guidance of Authors

In presenting the following notes regarding the preparation of articles for the JOURNAL, the Board of Editors hopes that the information contained may help authors and avoid alterations to drafts.

In addition to the specific points listed, the Board would like to remind authors that, of the 17,000 subscribers to the JOURNAL, at least 10,000 are members of junior grades, and that, if the JOURNAL is to be of maximum value to them, it is essential that the basic principle underlying any new system or device be explained simply.

TEXT.

1. Articles should be sent to the Managing Editor at least two months before publication date, i.e. by February 1st for consideration for the April

issue, May 1st for the July issue, etc. District and Institution notes should be sent five weeks before publication date.

2. Articles should preferably be typewritten. The typescript should be on one side of the paper only with double spacing and a wide margin. If a typewriter with mathematical characters is not available, formulæ and mathematical symbols should be written by hand.

3. Titles of articles should be concise.

4. Articles should be prefaced by a summary of 20-50 words and should not normally exceed 6,000 words, but longer articles may be accepted if they can be divided into two or more parts.

5. References to other articles should be included as foot-notes numbered consecutively throughout the text. Only the title of the publication in which the article referred to has appeared together with the volume number (if any) and page number should in general be given.

6. Main and sub-headings should be inserted. The paragraphs should not be numbered.

7. The use of the 1st person singular or plural should be avoided.

8. It would assist in editing if standard letter and graphical symbols are used.

ILLUSTRATIONS.

9. References to figures should be spaced as evenly as possible throughout the text and the number should not in general exceed two large or four small illustrations per 1,000 words.

10. Illustrations and diagrams should not be attached to the typescript, but enclosed with it and numbered clearly. They should be packed carefully so that they do not suffer damage in transit, particularly from paper clips, pins, etc. and the figure numbers should be written lightly on the back of a photographic print or on the border of a diagram.

11. A separate list of figures with their titles should accompany the article.

12. Block schematics and circuit elements should be used in preference to full circuit diagrams and unnecessary detail omitted.

13. The use of lengthy notes for reproduction with the figures should be avoided.

14. Line diagrams should be submitted in a form that can easily be traced, or, if a tracing is supplied, the lettering should preferably be omitted and given, on a separate sheet so that it may be inserted at a size suitable for the reduction decided upon.

15. Photographs should be printed on glossy paper, preferably full plate ($8\frac{1}{2}$ in. $\times$ $6\frac{1}{2}$ in.). Negatives are not required.

16. References, lettering, etc., to be added to a photographic print should be shown on a separate print or on a sheet of tracing paper covering the print.

17. When taking photographs, care should be taken to avoid unsuitable backgrounds.

Correspondence Regarding the Telephone Transmitter

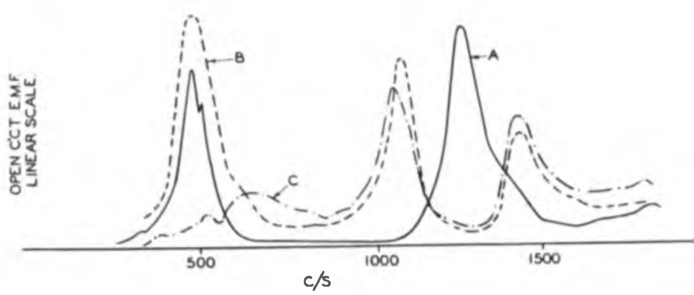
The Managing Editor,

DEAR SIR,—In his article on " A Method of Equalising the Frequency Characteristic of a Telephone Transmitter."[1] Mr. McMillan overlooks the assistance which may be derived from the direct measurement of the acoustic impedance of the quantities involved. Perhaps you will allow me the opportunity of indicating how valuable such measurements are to the designer of electro-acoustic apparatus.

It so happens that in the problem with which Mr. McMillan is concerned, three of the important quantities involved, S_1^1, S_2^1 and M_A^1 are amenable to calculation from dimensions, although there may be some doubt about the validity of the assumptions made in the calculations and also about the accuracy to which the dimensions Q_1 and Q_2 are known. Consequently, despite acknowledged ignorance of the magnitude of the associated acoustic resistances, it is possible to derive an impedance graph which is of considerable assistance in envisaging the modus operandi of the scheme of equalisation, and in determining the optimum values of the stiffnesses and masses to be employed in the final construction.

The writer was faced with a similar problem in equalisation some years ago when designing the present operator's breastplate transmitter. The difficulties were greater however, since the important acoustic quantities involved could by no means be regarded as *simple* stiffnesses and masses, and were therefore not amenable to calculation. Direct measurement was the only possible line of attack. The method of measurement employed has been described in the Engineering Supplement to the Siemens Magazine July, 1937 ; " The Vibrometer : A Device for Measuring mechanical and Acoustical Impedance."

The problem is illustrated in Fig. 1. Curve A shows the frequency characteristic for an Inset No. 10



A—WITHOUT ACOUSTIC MODIFICATION.
B—WITH RESONATOR (UNDAMPED) TUNED TO 1300 C/S.
C—WITH RESONATOR AND ACOUSTIC SHUNT IN THROAT.

FIG. 1.—OPERATOR'S BREASTPLATE TRANSMITTER.

when fitted with a mouthpiece of dimensions which make it physically suitable for use an as operator's transmitter. It will be seen that there is a very prominent peak at 500 c/s and another at 1,300 c/s. These peaks, particularly the former, have a most undesirable effect on the quality of transmitted speech.

It was necessary in the first place to be quite sure that the abnormally long mouthpiece was itself the source of these peaks. Acoustic measurements were therefore made on such a mouthpiece when closed at its throat end by a transmitter diaphragm, the remainder of the transmitter inset having been removed. (Using Mr. McMillan's nomenclature, Q_1 was made infinite and Sg zero.). The values

[1] Vol. 31, p. 299.

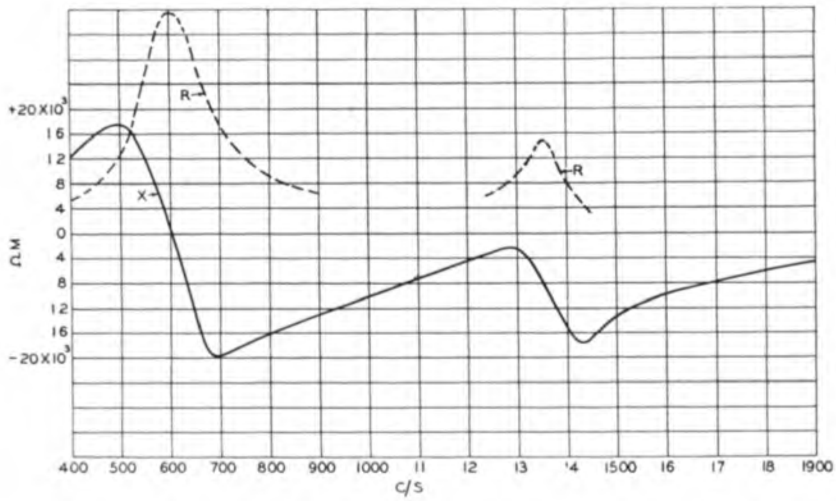


FIG. 2.—EQUIVALENT MECHANICAL IMPEDANCE OF OPERATOR'S TRANSMITTER MOUTHPIECE.

obtained are plotted in Fig. 2. In making these measurements separate readings are taken to eliminate the effect of M_d and S_d; consequently each ordinate in Fig. 2 is the mechanical impedance equivalent to the acoustic impedance of the mouthpiece alone, viewed from its throat end.

It will be seen that there is a prominent resonance at 600 c/s and another at 1,360 c/s. It has been shown elsewhere[2] that the corresponding zero values in the mutual impedance curve occur at slightly lower frequencies and, therefore, these two agree accurately with the peaks in the characteristic A of Fig. 1. This leaves little room for doubt that they could be dealt with by modifications to the mouthpiece alone, and from the numerical values given in Fig. 2, an indication of the magnitudes of the impedances which it would be necessary to add, is obtained.

An acoustic shunt or "leakage path" was inserted at the throat end of the mouthpiece; actually round the edge of the diaphragm itself. This eliminated the 600 c/s peak without affecting the performance at higher frequencies. In addition a simple acoustic resonator, having a natural frequency of 1,300 c/s was fitted halfway between the throat of the mouthpiece and its flare. The object of this was to produce the well-known "coupled-circuit" effect and so to broaden the 1,300 c/s peak and reduce its prominence.

The impedance curve of the mouthpiece so modified is shown in Fig. 3 and the corresponding frequency characteristics are B and C in Fig. 1. In B the 1,300 c/s resonator alone is fitted, but the resonator aperture is undamped. In C both the 600 and the 1,300 c/s modifications are in operation.

This problem, like so many others, could doubtless have been solved by the time-honoured procedure of trial and error. Perhaps it would have taken less time to produce an apparently satisfactory solution by such means. But no comprehensive understanding of any physical problem is possible without accurate measurement, and the trial and error method invariably leaves the designer with an uneasy feeling that a better solution could probably have been reached had he possessed a quantitative and complete knowledge of the variables.

Yours faithfully,

G. W. SUTTON.

Editor's Note:

Mr. D. McMillan has seen the above letter but considers that no reply from him is called for. He much appreciates Dr. Sutton's interesting additional information.

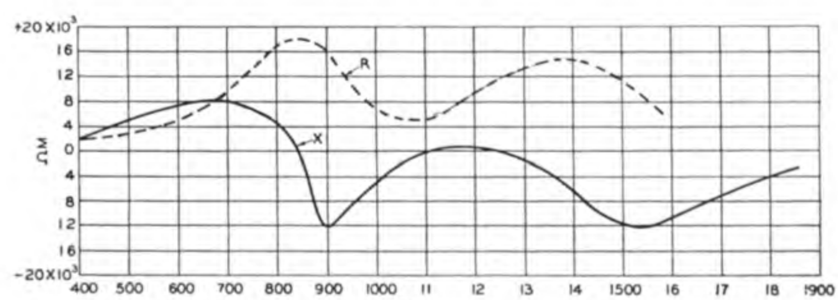


FIG. 3.—EQUIVALENT MECHANICAL IMPEDANCE OF OPERATOR'S TRANSMITTER MOUTHPIECE AS MODIFIED.

[2] *Eng. Supp. Siemens Magazine.* March, 1935. Fig. 8.

Local Centre Notes

North Wales Centre

The third meeting of the 1938-39 session took the form of a joint meeting of the North Wales Centre of the I.P.O.E.E. with the South Midland Centre of the I.E.E. under the auspices on this occasion of the latter body, the meeting being held in the Grosvenor Room of the Grand Hotel, Colmore Row, Birmingham, on Monday, December 5th, 1938, at 7.30 p.m.

These Annual Joint Meetings between the two Institutions have now become firmly established and many old aquaintances were renewed and new ones made at the informal gathering at tea to which I.P.O.E.E. members were kindly invited by the I.E.E. centre. This took place at the usual I.E.E. venue of the James Watt Memorial Institute which, on this occasion, was too small to seat the combined membership for lecture purposes. After tea members made their way to the Grand Hotel where approximately 150 members of the I.P.O.E.E. out of a total attendance of 397 were present for the main business of the evening, an attendance which was hailed as a record by the I.E.E.

The Chair was taken by Mr. H. Faulkner (Superintending Engineer, North Wales District), who is Chairman of the I.P.O.E.E. Centre and also Chairman of the I.E.E. Centre and acted in a dual capacity. After the Minutes of the last meetings of both Centres had been taken as read the Chairman called upon Mr. D. C. Birkenshaw and Mr. A. D. Blumlein to give their respective papers. Mr. A. D. Blumlein, B.Sc.(Eng), read the first paper—"The Marconi—E.M.I. Television System"—and Mr. D. C. Birkenshaw read the second paper, "The London Television Service."

Full copies of the two papers were available at the meeting and the authors gave a general resumé of the main features therein. At the conclusion of the reading of the papers the Chairman called upon Mr. Greig of the I.E.E. to open the discussion which was further contributed to by both I.E.E. and I.P.O.E.E. members. The Chairman, Mr. H. Faulkner, brought the discussion to a close and gave some interesting facts regarding the coaxial cable between London and Birmingham over which it is ultimately hoped to relay television programmes.

After the two authors had replied to the discussion a hearty vote of thanks was passed to them by the assembly in the customary manner on the proposition of the Chairman. The meeting then terminated at 9.5 p.m.

The fourth meeting of the session again took place in Birmingham on Thursday, January 12th, 1939, at 2.45 p.m., being held in the large hall, Queens College, Paradise Street, Birmingham.

The Chairman of the Centre, Mr. H. Faulkner, presided over an attendance of 180 members and visitors, the latter including representatives of the District Managers' Staffs at Chester and Gloucester; the traffic staff of the Birmingham Area Manager; Mr. J. A. Cooper, Chief Engineer of the B.B.C., Midland Region, and Staff; and representatives of the Electrical Engineering Branch of Birmingham University. The Chairman welcomed the visitors and two new members who brought the Centre membership up to 374.

On this occasion the Centre had the pleasure of hearing Mr. A. H. Mumford, B.Sc.(Eng.), A.M.I.E.E., Staff Engineer, Radio Branch, Engineer-in-Chief's Office, give a paper on "Test Results and Commercial Operation of the London-Birmingham Coaxial Cable System." The paper was delivered extempore and proved Mr. Mumford's perfect mastership of his subject. The paper, together with a resumé of the system, was in the nature of a continuation of the articles on the Coaxial Cable which have appeared in various issues of this JOURNAL.

At the conclusion of the paper the Chairman called upon Mr. Peck to open the discussion. Mr. Peck, in complimenting Mr. Mumford on an excellent paper, said that one could always tell when a trunk call to London was passing over the coaxial cable by the bell-like clarity and absence of noise, which, when the various phases of modulation and de-modulation, etc., were taken into account, was a tribute to the designers of the system. Even with this super-system one could not get away from the ubiquitous dry joint which Mr. Mumford had shown in the list of faults as causing a temporary breakdown on occasion. Many members took the opportunity of discussing the paper and the Chairman, concluding the discussion, said that the coaxial cable system was a good example of what one might do with resistances, inductances and capacitances.

Mr. Mumford replied in full to the discussion and gave further interesting points with regard to the check upon the accuracy of the master oscillator crystals.

A hearty vote of thanks was passed to Mr. Mumford for a very enjoyable paper by the meeting which closed at 5.40 p.m.

The fifth meeting of the session took place at the usual Shrewsbury venue, the Technical College Hall, on Thursday, February 9th, 1939 at 2.45 p.m. when Mr. G. T. H. Matthews of the Birmingham Area Development Staff gave an interesting Paper on "Development Schemes."

In the absence of the regular Chairman, Mr. H. Faulkner, on official business, the Chair was taken by the Vice-Chairman of the Centre, Mr. H. G. S. Peck.

The attendance, with the usual visitors from the various District Managers' Staffs, numbered 182. The Chairman after welcoming the visitors announced that as a result of five further new members the Centre membership now stood at 379.

Mr. Peck then called upon Mr. Matthews to deliver his paper which dealt very fully with the subject.

In opening the discussion Mr. Pope, Sectional Engineer, Chester, said that the reproduced copies of the papers would be especially valuable to those junior members of the staff who might desire an insight into this interesting subject.

Many members took part in the discussion which was brought to a close by the Chairman speaking on the difficulty of trying to estimate development for large country estates near towns which might be housing estates in 20 years' time.

A hearty vote of thanks was passed to Mr. Matthews after replying to the discussion and the meeting terminated at 5.30 p.m. S. T. S.

Junior Section Notes

Cambridge Centre

The Cambridge Centre continues to flourish. For this session the Centre has a membership of 60.

Due to circumstances beyond our control, the opening of the session had to be delayed and eventually the opening meeting was arranged for November 25th, when an extremely interesting lecture and demonstration was given by Mr. A. J. Thompson on " Fault Localisation, Main and Local Cables." At this meeting the Area Engineer, Mr. J. E. Pidgeon, presented two awards won by members of the Centre, for papers read before the Junior Section during the 1937-38 session. The first was a cheque for one pound and a certificate to Mr. J. C. Robarts, and the second a cheque for ten shillings and a certificate to Mr. J. E. Boon. The award to Mr. Robarts was kindly given by Mr. W. M. Osbourne (who was Sectional Engineer of the Cambridge Section prior to his promotion to Assistant Superintending Engineer). Mr. Boon's award was in connection with the Eastern Centre Essay Competition which is open to all members who fail to gain an award in the national essay competitions.

On December 20th a paper was given on " Transmission " by Mr. C. Riley. On this occasion the Centre was fortunate in having demonstrations given on apparatus loaned from Dollis Hill.

The meetings continue to be well supported both by junior members and members of the parent body.

January 27th, saw a slight change in the usual type of paper given by our members, when Mr. J. H. Cater gave a paper, entitled " Aeronautics." This proved to be extremely interesting, a large number of questions being put to the speaker. The paper dealt chiefly with " Aero Dynamics."

On February 24th a paper was given by Mr. J. E. Boon on " U.A.X. Junction Equipment."

Forthcoming events are :—

March 24th—" Local Line Development." G. W. Harvey.

April 21st—" Radio Interference Suppression." L. Salmon.

Grantham Centre

At a meeting held on January 10th it was unanimously agreed that a Centre be formed at Grantham, and the following officers were elected :

Chairman : E. A. Owen.
Vice-Chairman : R. Morley.
Secretary : G. J. Ward.
Treasurer : J. M. Bagley.
Committee : T. J. H. Gaut, R. J. Owen, H. Kidd, J. H. Cheatle and R. C. Wray.

There was a good attendance, including J. Mc.A. Owen, M.I.E.E., Sectional Engineer, who explained the objects of the Junior Section, and Mr. C. Welch who dealt with the financial side of the centre.

The meeting closed with a vote of thanks to Mr. Owen and Mr. Welch for their interest in the matter.

A short programme has been arranged for February, March and April.

Until the next session will members please watch the notice boards. A. J. W.

Luton Centre

Despite the various counter attractions which prevail throughout the winter months, the Luton Centre is flourishing and a very keen interest is being displayed by the staff.

The 1938-39 session commenced on September 22nd, 1938, when at a general meeting the following officers were elected :—

Chairman : O. H. Budd.
Vice-Chairman : R. Little.
Secretary and Librarian : J. A. Pyper.
Treasurer : N. Beswick.

The Sectional Engineer, Mr. J. B. Salmon, attended a meeting on Thursday, November 17th, 1938, when the Chairman, Mr. O. H. Budd, gave an excellent paper entitled, " London-Birmingham Coaxial Cable."

A number of other meetings have since been held, but it would entail too much space to report on them.

In addition to the programme of lectures which have been compiled for the 1938-39 session, a series of " Discussion Nights " is to be held. These discussion nights are primarily intended for the benefit of members who are taking correspondence courses, to enable them to discuss points of difficulty encountered in their lessons.

Arrangements are to be made in the near future for educational visits to places of technical interest. It is hoped that members of the junior staff, both internal and external, will avail themselves of this opportunity to further their technical knowledge by attending the very interesting meetings that have been arranged, and also by taking advantage of the excellent library facilities available.

Oxford Centre

The fourth paper of the 1938-39 session was read by Mr. H. Bett to an appreciative audience on Monday, January 16th.

The subject " Local Line Development " was clearly and carefully explained from the commencement of a scheme to the conclusion of the work. Mr. Bett went to great trouble in preparing maps and other details.

The discussion was opened by Mr. Robinson. Points raised were dealt with to the satisfaction of all present by Mr. Bett.

The attendance was not up to standard and the members who were absent missed an excellently read paper. J. M. N.

Preston Centre

The advertised date of our February meeting was departed from in order to pay tribute to Mr. S. J. Cain, Efficiency Engineer, before his departure from the North Western District to take over a similar duty in the South Midland District.

The meeting was held on February 3rd at the Head Post Office, Preston.

Mr. W. H. Eaton presented his paper " Local Line Development " in a very able manner, the resultant discussion proving of interest to all present, including a number of members of the Senior Sections.

After closing the business of the paper, the Chairman invited Mr. T. Singleton, gang foreman, Preston, to take over the duties of the chair. Mr. Singleton spoke in a very pleasing manner of the kindness, willingness, and the humane understanding which Mr. Cain had shown to all while carrying out his duties as Efficiency Engineer ; and that he esteemed it a real pleasure to be afforded the honour of presenting, on behalf of the workmen of Preston, Blackpool, Southport and Wigan, a small token of their respect and appreciation of his valued service.

Mr. Singleton presented to Mr. Cain an electric timepiece and a silver vase for Mrs. Cain. Acknowledging the presentation, Mr. Cain spoke of the loyalty, support and co-operation which he had always received, and on behalf of Mrs. Cain and himself, thanked all associated with the gifts. They would always serve to remind him of his happy associations in the North Western District.

Mr. H. M. Taylor, Executive Engineer, in supporting the presentation, paid tribute to Mr. Cain's outstanding qualities, and assured the meeting that no greater compliment could be paid to an Engineer, than to be the recipient of such goodwill and respect from the workmen.

Mr. H. Crook, S.W.1, on behalf of the mechanics and Internal Staffs paid tribute, and concluded by wishing Mr. and Mrs. Cain every success in the future.

C. J. B.

Southampton Centre

An interesting and comprehensive paper entitled "An Outline on Regional Working" was read before the Southampton Junior Centre on Wednesday, January 18th, by F. W. Friday, Esq., A.M.I.E.E. (Sectional Engineer). Among the visitors present were representatives from every branch of the Southampton Section, including the clerical and traffic staff.

The paper gave an excellent description of the development of the Departmental Organisation from National Telephone Company's practice to Regional Organisation. Many questions were asked, to which Mr. Friday gave adequate replies. A cordial vote of thanks was moved by Mr. R. J. White, seconded by Mr. C. H. Lockyer and carried with acclamation.

Our Winchester and Salisbury colleagues who have supported the Centre are welcomed heartily. We also congratulate Ryde, Isle of Wight, on the formation of a new Centre.

The Committee welcome also suggestions and subjects for discussion during the 1939-40 session. These may be given to Mr. Hale, Chairman, or to Messrs. White, Hislop, Couzens, Jennings, Middleton or Dodridge.

The continued support which Senior Section members have given to the Junior Section is appreciated.

N. E. D.

Southend-on-Sea Centre

Interest in the activities of the Junior Centre has increased, meetings for December and January being well attended.

The subject for December was "Speech Night."

Nine ten-minute speeches were made by various members of the Centre. The subjects included, Illumination, Stamp Selling Machines, Tones, Single Battery Power Plant, U.A.X. 7 and 14, Speaking Clocks, and Barretters.

There was a short discussion after each paper. The judges for this occasion had a difficult task. Their decision was that the prize of 10s. 6d. for the best paper of the evening be awarded to J. Garlick for his paper on "Tones."

On the occasion of our January meeting a joint paper on Local Development Schemes was read by Messrs. Nicholls and Pfaffle.

The presence at the meeting of members of the external staff helped to make the discussion on this paper very interesting.

Papers for the remaining meetings of the session are :—

February 28th—" P.A.B.X." H. Norman.
March 28th—" International Radio." R. G. Martin.
April 25th—" Metal Rectifiers." J. Garwick.

Swindon Centre

A meeting of the staff was held on January 20th with our Sectional Engineer, Mr. Gifford, as Chairman, supported by Messrs. Clarke (secretary Senior Section South Wales District), Gill (Efficiency Engineer, South Wales District) and Kibby (Efficiency Inspector), with the object of forming a Branch of the Junior Section at Swindon.

The Chairman and his colleagues gave interesting and valuable information on how to form and run such a Branch and the enthusiasm of the meeting was such that it was unanimously decided to establish a Centre at Swindon and a small temporary Committee was elected for the purpose.

This Committee met on February 13th and elected the following officers for the ensuing year :—

Chairman : E. Blewitt.
Vice-Chairman : A. E. Griffiths.
Hon. Secretary : G. A. C. Coombes.
Hon. Treasurer : E. F. Pearce.
Committee : E. J. Turner, J. Bray, A. W. Smith

District Notes

London Region

STORM DAMAGE

The heavy snow storm which occurred in London and the Home Counties on Wednesday January 25th, proved to be one of the worst for many years from the point of view of damage to the overhead telephone plant in the London Region. The Areas most affected were the North-West and North where the number of subscribers' circuits out of order on January 26th was 9,653 and 7,861 respectively the total for the Region being 27,335.

Owing to the extremely wet and heavy nature of the snow, hundreds of poles were brought down, broken or displaced, with the result that there were 93 exchanges in the Region on which the subscribers' faults exceeded 50, over half of these exchanges being situated in the North-West and North Areas. Among the exchanges most adversely affected were St. Albans with 2,000 lines out of order, Watford 1,050, Pinner 890, Northwood 630, Rickmansworth 600, Enfield 600, Uxbridge 600, Enterprise 540, Palmers Green 520, and the following exchanges each with 500—Buckhurst, Harrow, Hillside and Ruislip. Five small exchanges in the South-East Area were isolated but the junction routes affected were restored on the day after the storm. Extensive damage was also caused on the Barnet-St. Albans, Potters Bar-Brookman's Park and Tottenham-Broxbourne trunk routes. The number of circuits affected was however small, as these routes carry a high proportion of spare wires.

On January 26th all the overhead gangs that could be possibly released from the Areas where the faults were relatively small were moved to the badly affected areas and the maximum amount of time allowable in the relatively short days was put to the restoration of the circuits. All Advice Note work necessitating overhead gangs had to be postponed for a considerable period. Within eighteen days all the faulty circuits were restored —a considerable proportion, of course, only on a temporary basis. In the North Area alone there were over 220 overhead men employed on the work at one period, and the figures for the other Areas were of similar dimensions.

It is estimated that two to three months will elapse before permanent restoration can be effected and this work will make a heavy demand on the normal staff employed on faulting and Advice Note work. Great credit is due to the staff for their unsparing labours in effecting the restoration of the circuits, especially in view of the transport difficulties encountered the first few days after the storm. There were, of course, complaints from quite a few subscribers with regard to delay in restoring their service, but generally they were very appreciative of the difficulties.

KINGSTON-ON-THAMES POWER SUPPLY FAILURE

A complete burn-out of the power station at Kingston-on-Thames took place late in the afternoon of December 14th, 1938, as a result of which the power supply to nine exchanges in the South-West Area failed about 4.20 p.m. The exchanges concerned, all of which are manual with the exception of Richmond (Director Auto.) were as follows :

Kingston, Molesey, Richmond, Emberbrook, Walton-on-Thames, Esher, Weybridge, Elmbridge, and Popesgrove.

Enquiry was immediately made from the Borough Electrical Engineer at the power station, as to the possible duration of the breakdown and it was learned that it was likely to last for several days. A review was made of the amount of reserve battery capacity at all the exchanges concerned, and operators were retained to deal with the additional traffic. The power supply at Elmbridge, Emberbrook, Esher and Popesgrove, was reconnected within a few hours.

Immediate arrangements were put in hand to get the 67 kilowatt Beardmore set and an 8 kilowatt set to Kingston during the night. The power staff concerned were delayed in reporting for duty by dense fog which also delayed the arrival of the charging sets. However, these two sets arrived in Kingston about 5 a.m. on 15th instant. Arrangements had been made over-night to get the remaining available 8 kilowatt sets into the area early the next morning. Only one of the 8 kilowatt sets were however, available, since four 8 kilowatt sets were in use at Guildford, Oxford, and with the Film Unit, Blackheath. Early on December 15th, 1938, arrangements were made to recall one set from Oxford and the one with the Film Unit. These came to hand during the afternoon of the 15th instant. By means of these sets the service at all the exchanges concerned was maintained.

The duration of the breakdown of the power supply for the various exchanges was as follows :—

Richmond	4.20 p.m., December 14th, 1938
	to 6.8 p.m., December 15th, 1938
Kingston	4.20 p.m., December 14th, 1938
	to 1.30 a.m., December 16th, 1938
Walton-on-Thames	4.20 p.m., December 14th, 1938
	to 5.50 p.m., December 16th, 1938
Molesey	4.20 p.m., December 14th, 1938
	to 7 p.m., December 15th, 1938
Weybridge	4.20 p.m., December 14th, 1938
	to 5.30 p.m., December 16th, 1938

The breakdown at the other four exchanges lasted only a matter of a few hours.

The failure of the power supply also affected teleprinter working from various Post Offices in the area, and emergency equipment was installed at Weybridge to expedite service.

The load on several of the exchanges increased very appreciably during the breakdown, on the average from two to three times the normal. As a result a revision of the initial arrangements, having regard to the estimated urgency of particular exchange requirements, was necessitated. At two of the exchanges the emergency set was connected only a short time before the batteries would have failed. As a result the only practicable way of furnishing power to the exchange from the emergency set was by floating. A choke coil which had been part of the permanent charging equipment at Kingston exchange was cut out of circuit and used at other exchanges.

NEW AUTOMATIC EXCHANGES

Park. The Park manual exchange was transferred to automatic working at 2 p.m. on December 3rd, 1938. The automatic equipment forms the second unit in the Bayswater automatic exchange building, and was installed by Standard Telephones & Cables, Ltd. The initial equipment capacity is 5,900 with an ultimate of 10,000. 4,523 subscribers, 541 outgoing junctions and 603 incoming junctions were cut over at the transfer. This equipment includes over 600 line finders with the associated subscribers' calling equipment, 400 first code selectors, 80 directors, nearly 1,500 200 outlet, group selectors, and nearly 600 final selectors of various types. The bridge control manual board which originally served Bayswater exchange was replaced by a sleeve control manual board to carry the auto. manual traffic, including toll traffic for the two exchanges. The Bayswater power plant, which was of the Department's standard two battery charge discharge type, was converted to parallel battery float working and one additional motor-generator with an output of 200 amps was installed.

Popesgrove. 4,100 subscribers' lines working on Popesgrove manual exchange were transferred to new automatic equipment installed in an extension of the existing building at 1.30 p.m. on January 11th. The automatic equipment which has an initial capacity of 4,900, ultimate 10,000 was supplied by Messrs. Siemens Bros. & Co. Ltd., the batteries being installed by the Hart Accumulator Co., Ltd. These batteries are associated with divided battery float power plant and are plated to 1,200 ampere hours with a box capacity of 1,650 ampere hours. The auto. manual board traffic is dealt with at Prospect where a new sleeve control suite has been fitted to deal with the manual board traffic for Prospect, Richmond and Popesgrove. 368 outgoing junctions and 317 incoming junctions were also brought into use at the transfer.

Essendon. This U.A.X., of the No. 6 type, was replaced on February 15th by a No. 13 type in a new and larger building, situated on the same site. Considerable difficulty was experienced in accommodating this building on the existing site owing to space limitations of the latter due to the increase of building line depth for future road widening. The manual board is at Potters Bar C.B. exchange and the number of subscribers transferred was 94.

P.A.B.X's

J. & E. Hall, Ltd., Dartford. This subscriber was served by a Relay P.A.B.X. 32 volt equipment but the manual board was destroyed by fire some months ago and temporary manual working resorted to. Two new sections B.E.C.B. No. 9 have now been installed to serve as an auto-manual switchboard, the cord circuits having been modified to meet the non-standard engaged test conditions provided by the automatic equipment. There are 131 working extensions, 15 exchange lines and 2 private wires and the 12-cord circuits on each position incorporate individual sleeve relays per cord controlled by metal rectifiers to perform the necessary switching functions. One 16 cell battery serves the equipment and is float charged by a Siemens Transrecter with automatic voltage control.

R.A.C.S. Woolwich. This equipment of the P.A.B.X. line finder type has recently been completed by Messrs. Ericssons and serves at present 145 extensions and 37 exchange lines. There is a 5-position manual board with 16 cords per position and free line signals on the outgoing multiple. The power plant is of the Parallel Battery Float system supplied from A.C. Mains and incorporating two 125 ampere hour batteries. 50 point uniselector line finders and 100 outlet two motion group and final selectors are employed in the automatic switching plant.

P.B.X's.

Air Ministry, Berkeley Square House. The opening by Sir Kingsley Wood of the new Air Ministry Headquarters at Berkeley Square on December 6th marked the completion of one of the largest block wiring schemes ever carried out in the London Region. The building is wired for 2,400 extensions and 750 main cable pairs are terminated on the main frame installed in the basement and on which the building cables to the various floors are terminated. The work of wiring the building was carried out under considerable difficulty owing to the number of contractors striving to complete the building in the limited time available but, as a result of the efforts of the Post Office staff, service was given at the date required. In view of the very short period available for installation of the P.B.X. it was necessary to instal a 16-position, C.B. No. 9 manual switchboard at the outset, with temporary 126 ampere hour batteries. The permanent installation, which will consist of 32 C.B. 10A positions with a power plant with two 1000 ampere hour batteries which can be worked charge-discharge or float, is now under construction. The power plant will be supplied from four 40 volt rectifiers worked off 400 volt A.C. mains.

Telegraphs.

In November last, a new teleprinter school on the 4th Floor, C.T.O. Building was opened for training purposes, replacing the old school on the ground floor. Regulation tables have been installed for 20 practice sets, especially wired for alternative teleprinter No. 7B and No. 3A working for "through," "local" or normal conditions. A further 50 sets have been installed for local practice purposes using teleprinters No. 3A. All circuits provided have been wired to a test board in the lecture room adjacent and can be adapted for traffic purposes if necessary, during peak demands. In addition, two telex circuits have been provided on National exchange.

During the last few months, multi-channel V.F. telegraph working between London, Birmingham, Cardiff, Exeter, Nottingham and Sheffield has been introduced using channels of the 12-circuit carrier telephone systems. Additional testing equipment has been installed to deal with the growth of these systems and additional cables are being provided for the extension of the circuits from the V.F. telegraph plant in Faraday Building to the instrument terminations at C.T.O. A further bay of Tariff "A" equipment has been installed at Faraday Building for additional requirements of 56 subscribers.

Trunks.

New suite of trunk and toll test racks. The whole of the trunk and toll circuits have now been transferred from the old to the new test racks and this involved the provision of more than 57,000 new jumpers using nearly 500 miles of twin jumper wire. In addition, nearly 27,000 old jumpers had to be recovered. The work of diverting these circuits was extremely complicated as it was necessary to ensure the minimum interference to trunk and toll traffic and, with careful organisation, it was possible to keep this interference down to an absolute minimum.

London-Birmingham coaxial system. Two super-groups of 40 circuits each, together with common equipment have now been completed and are giving satisfactory service on the Birmingham route.

12-circuit Carrier systems. Early in December, the first four groups of the London-Bristol 12-circuit carrier telephony circuits were lined up and handed to traffic and the remaining 20 groups in this sytem are being brought into use gradually, together with other trunk re-arrangements.

Work is now in completion on the London-Oxford-Gloucester system ; at the moment groups 18 to 21, i.e. 48 circuits, are in service under acceptance tests. A second four groups are almost ready and are under test by the Contractors.

The London-Cambridge system is nearing completion but no circuits are as yet in service, while the London-Guildford-Portsmouth is well advanced with the installation almost completed.

The London-St. Margarets Bay carrier cable has been brought into Faraday Building and terminated, and the installation of the channel equipment is proceeding. The London-Salisbury carrier cable has also been terminated and proportion of the channel equipment is on site. 788 echo-suppressors are being installed in conjunction with the above systems.

6th Floor Main Trunk Suite. On December 19th, 1938, 38 demand positions on the 6th Floor Main of the South building were opened to traffic to meet the Christmas pressure and deal solely with calls originated from automatic exchanges in the London Director area. The opening of this suite brought the total of positions in Faraday Building set aside for long distance traffic to 802. The initial suite on the 6th Floor Main comprises 106 trunk positions, the completion of the balance being due in a few weeks.

2 V.F. and 7 Digit Director equipment. An automatic exchange of the director type will shortly be opened at London Trunk exchange. At present individual selector lines are provided to each automatic exchange in the London Area and the trunk operators obtain the number required by dialling 4 digits, whereas on the opening of the new exchange, a common group of manual board first code selectors will give access to all automatic exchanges in the London director area, the operators dialling 7 digits for each call, that is the three digits of the exchange code followed by the 4 numerical digits.

The existing circuits to the automatic exchanges appear in the outgoing junction multiple but, on the introduction of the new scheme, these circuits, plus additional junctions necessitated by the change from manual selection to automatic selection, will be transferred to the bank contacts of the code switches. 800 keys have been provided in order that the transfer of the junctions concerned approximately 650, may be effected without interference to the service. Owing to the limitations of multiple capacity it will not be possible to accommodate the whole of the manual board first codes at the outset and it will thus be necessary to introduce automatic working exchange by exchange, thus releasing multiple jacks for gradual extension of the manual board first code multiple.

Two V.F. signalling equipment to enable provincial zone centre operators to dial direct into the London automatic network is at present under extensive test and it is anticipated that the first groups of trunks working on this system will be brought into use during the next few months. Change-over keys are also being fitted on the trunk circuits to facilitate testing and change-over to the new conditions. In view of the fact that group centres working direct to London are not at present being equipped for 2 V.F. working, it has been decided that certain of the larger automatic exchanges in the City and West End shall retain a four digit dialling group of junctions from the trunk multiple in addition to the provision of an automatic group from the code switches, the latter being used for calls from zone centres and for over-flow traffic from the four digit group passed via the London manual board first code.

South Eastern

SEA CABLES—ST. MARGARET'S BAY

Two works of interest have been carried out recently in the Canterbury Section, both in connection with the shore ends of sea cables at St. Margaret's Bay.

The first work concerned a subsidence of the footway above the sea wall—shown in Fig. **1**. The main point of interest, however, lies chiefly in the cause of the subsidence, which was found to be a concrete ramp constructed for leading in some of the early sea cables which have since been abandoned. Unfortunately this heavy ramp was not taken down to the solid chalk-rock footing but was built on shingle. The action of the tides has slowly shifted the shingle, undermining the security of this ramp, with the consequence that it eventually broke away, carrying a small portion of the base of the wall with it. Once a small opening was made in the wall the tide washed out the shingle from behind the wall, causing the footway to fall in. It is somewhat surprising to note how rapid is the action of the sea in washing away loose material, although the hole through which it swirls is comparatively small. The hole, which measured roughly 8 ft. by 6 ft. at the top, was made during the night by one tide. Although in the height of the holiday season the bay is very popular with visitors, at this period of the year fortunately few persons pass that way. However, as the subsidence occurred immediately in front of and close to the original cable hut, which is now the property of a local landowner, a second tide would probably have seriously affected the safety of this structure.

FIG. **1**.—FOOTWAY SUBSIDENCE.

In making repairs it was considered desirable to carry the reinforced concrete well below the hole in the wall, in order to avoid possible trouble in the future from apparent cracks. This, although necessitating excavation to a depth of approximately 18 ft. and close timbering as the work was in loose chalk and shingle, presented little difficulty other than a suitable choice of time for working in relation to the tides.

FIG. **2**.—COMPLETED REPAIRS.

Fig. **2** shows the substantial nature of the final repairs on the face of the sea wall, and also the end of the old concrete ramp.

The second work concerned the leading in arrangements for the shore end of the new TSX-Sangatte cable, which will be landed this spring.

Previously, cables have been taken through a hole in the sea wall and laid in a trench on the land side. It was decided in this instance, however, to lay a 6-in. pipe to carry the new cable and to provide three similar pipes for future cables, making four in all. The type of pipe to be used was given careful consideration and it was finally decided to use metal spun cast iron pipes 6 in. in diameter, the four pipes passing through the sea wall being "C" class, i.e. 0·37 in. in thickness and the remainder Class B 0·33 in. in thickness. Metal spun iron pipes have the advantage over the usual cast iron pipes of greater strength, a reduction in weight, with a consequent saving in freight charges, and a much smoother bore; the latter has a distinct advantage when drawing-in large diameter, heavy, covered cables. In this connection it is desired to record the able and willing assistance given by the Staveley Coal & Iron Company from whom the pipes were purchased.

The pipes terminate on the land end in a manhole—RC.2 reduced to 8 ft. long—and as it is necessary to provide for adequate anchoring of the sea cables the pipes have been arranged to enter in pairs vertically against the sides at one end. At the opposite corners two anchor irons per pipe have been provided.

The method decided upon for anchoring the sea cables is to cut back the armouring and form this into two wire ropes each moored to a separate anchor iron by a length of G.I. stay wire, the ropes so formed and the stay wires being coupled with stay clamps.

The laying of the pipes presented no little difficulty; in the first instance the trench was in loose chalk and shingle, terminating in a tunnel for the last six yards back of the sea wall. Close timbering was essential throughout. Secondly it was necessary to choose a suitable time to break through the sea wall as at this point it is well below high water level. Although every effort was made to break through, lay pipes and fill-in in one day, with the short days at this period of the year it was not found possible to do so, and temporary filling-in was necessary. In order to reduce the work of filling-in and re-excavating to a minimum, temporary filling-in was made with sacks loosely filled with shingle and these were readily lifted into position and removed as required.

Sacks filled with shingle were also used as a barricade in place of timbering on the sea side to prevent the tide washing shingle back into the open trench.

Referring to the tunnel to the back of the sea wall it should perhaps be mentioned that several very large sections of old concrete sea wall—which presumably at some previous date had fallen in and been abandoned—were encountered and these had to be broken up before they could be removed.

During the work here another small subsidence occurred ; although this was some little distance away from the present work, its course has been traced to the back of the hole in the sea wall through which previous sea cables have been led-in. The cause of this subsidence appears to be due to the fact that the sea washes up the hole and subsequently drains away under the base of the sea wall—the sea wall is not carried down to the rock-chalk but rests on shingle, gradually carrying with it loose chalk and the finer shingle. It is proposed, therefore, to seal the hole in the sea wall with compound round the cables and concrete the whole in situ.

Two photographs of this work are reproduced and these show various aspects and points of interest.

Fig **3** shows a close up of the sea end of the trench and gives some idea of the tunnelling. Practically the whole of the depth shown is below high water level and as can be

FIG. **3**.—TUNNELLING UNDER SEA WALL.

seen the excavation is in loose shingle, which tended to level out on each occasion water entered. The existing sea cables are shown suspended. A point of economy in timbering material will perhaps also be noted.

Fig. **4** shows the work completed. The ends of the four pipes have been sealed with caps. It is the intention, however, when the sea cable is drawn in, to have a split cap specially made to fit over the cable to enable the pipe to be efficiently sealed to prevent the ingress of water.

This photograph was taken before the timber guard was replaced. It is, however, being replaced temporarily. Before the sea cable is drawn in the piles will be placed in

FIG. **4**.—NEW PIPES IN POSITION.

positions more suitable for the run of the cables and a new guard erected.

It will be appreciated that the photographs from the beach were taken at low tide. At high tide the water reaches practically to the top of the wall. There is, moreover, a very big difference in the level of the shingle at different periods—with some tides the level of the shingle is raised so as to cover the whole of the work, whereas at other times the shingle is carried clear away.

STORM DAMAGE

As a result of the snow storm on January 25th, 1939, very extensive damage was caused to the line plant in the South Eastern District. The eastern area of the District suffered most but the central and western areas were also badly affected. Details from the various areas are as follows :—

Tunbridge Wells Area

The snow commenced early in the morning of January 25th, 1939 and continued steadily throughout the day. By 5.30 p.m. the total number of reported faults was approximately 2,600 with 20 exchanges reported on January 26th, 1939 as totally isolated ; by 4 p.m. on January 27th the faults had risen to over 5,000.

Repair work was by this time well in hand and every effort was being made to restore service in the isolated areas ; so expeditiously was this done that by 4 p.m. on January 27th, 1939 only 2 exchanges remained isolated.

Storm repair work continued until February 6th, 1939 when a normal fault position had been reached and up to that time approximately 7,000 faults had been cleared.

Pole breakages were comparatively slight in view of the heavy strain imposed upon the routes generally, the total of 20 such breakages being surprisingly low due undoubtedly to the ground being waterlogged. The total number of poles deflected, however, amounted to approximately 480 and those uprooted numbered 85. The number of broken stays numbered 25 with approximately 75 drawn and 10 arms were broken.

Repair work was greatly hampered by the heavy night frosts which continued throughout the week following the storm and which broke the badly strained wires that had been replaced to give temporary service.

The following junction routes broke down entirely :—

Sharpthorne-East Grinstead
Tonbridge-Hadlow
Rotherfield-Crowborough
Danehill-Nutley
Penshurst-Tonbridge

Collier Street-Paddock Wood
Tunbridge Wells-Crowborough
Tunbridge Wells-Rotherfield
Heathfield main route
Hadlow Down-Buxted
Penhurst-Tunbridge Wells
Horsmonden-Goudhurst-Brenchley

Canterbury Section

In this Section, the fall of snow was heavy and the line breakages were due entirely to the weight of snow and ice on the wires, there being no wind to increase the damage. As a result approximately 100 poles were broken, 1,150 poles required resetting, 1,200 miles of single wire had to be renewed, about 5,000 telephone subscribers were without service and 17 exchanges were isolated.

As the snow melted the flooding which occurred loosened the soil around the base of many poles causing them to go over under the strain of broken wires and poles. The flooding was therefore responsible for increasing the already high number of poles that required resetting and also for causing 20 cable faults, all these being in cables the lead sheathing of which had been previously corroded.

After the roads had been cleared of broken poles and tangled wire, the work of restoring the service was energetically tackled. By January 1st, 1939 all the exchanges had been brought into service and the number of outstanding faults reduced to approximately 1,500. It took nearly three weeks for all the faults to be temporarily cleared.

Brighton Area.

The storm affected chiefly the North-Eastern part of this area and approximately 5,000 faults were caused mainly due to single spans of wire. About 50 poles had to be reset and 3 exchanges were isolated for the period from the afternoon of January 25th, 1939 until the morning of January 26th, 1939 when in each case service was restored. The faults were reduced to a normal number in about 9 days.

A. B. M.

South Lancs.

RUSHOLME—NEW 3,000-LINE, 2,000-TYPE AUTO EXCHANGE

On January 28th, 1939, at 1.1. p.m. the first large 2,000-type exchange in the Manchester Director network was cut into service with a total of 2,751 lines and 446 junctions.

The call office traffic (180 installations) is high in this area and the transfer of these to the automatic equipment was spread over the previous ten days, during which any incoming calls to transferred lines were completed via transfer circuits from the C.C.I. positions to an "A" operator who dialled the required number. For outgoing calls from these numbers a temporary director translation was inserted to route calls to other Rusholme subscribers via tandem to the C.C.I. positions at the manual exchange.

For the pre-transfer testing arrangements, AUT translations were provided on the directors at outstation exchanges to enable the auto exchange to be obtained without interference with the routing of RUS calls to the C.C.I. manual positions. Before the transfer half of these were removed and the directors busied until the transfer and the remainder were modified immediately afterwards.

The post-transfer engineering tests were commenced at 1.5 p.m. and completed by 1.35 p.m.; the traffic tests were finished at 3.45 p.m. Two faults were proved—1 line and 1 instrument—and succeeding weeks have had normal fault rates.

The old Rusholme exchange—the second C.B. exchange to be opened in Manchester about 1909—is of interest being in an adjacent single storey building, once a laundry. The equipment is a Western Electric C.B.10 with small line relays mounted in the sections. Good use will be made of this building as a Works Order Store.

Thus, after several vicissitudes during which the ready for service date successively moved from June 1st, 1937 to November 14th, 1938, the new Rusholme is now a "fait accompli."

South Midland

HURLEY VILLAGE AUTOMATIC EXCHANGE

By the time this article appears in print the above will be no more; it will have been replaced by modern equipment of the U.A.X. No. 13 type.

Hurley together with Ramsey (Hunts.) were the first unattended public exchanges to be installed in this country and no doubt the experience gained from the working of these exchanges, proved to the Department that the elimination of small manual exchanges by automatic equipment was a step in the right direction.

It may be of interest to the modern telephone engineer to compare the equipment installed by Messrs. Siemens Bros. in December 1921 with that installed in January, 1939—just over 17 years. It will be noted that several of the features then installed, are now standard on the modern equipment.

	Old	*New*
Calling equipment	U.S.	L.F.
Dialling tone	No	Yes
N.U. tone	Yes	Yes
Multi-metering	No	Yes
Extended alarm over junction	Yes	Yes
Single Sided Racks	Yes	Yes
Busy Back and Flash	Yes	Yes
Interrupter Springs on Ringer	Yes	Yes
Coin Box facilities	*No	Yes
P.B.X. facilities	*No	Yes

*These could have been provided but were not called for in the specification.

The old village equipment was initially installed for 40 uniselectors and ultimately 80, the numbering scheme being 20-99. The bothway junctions to Maidenhead (parent exchange) and to Marlow were connected to the 0 level and to obtain these exchanges 01 and 02 respectively had to be dialled, the hunting feature being provided on level 0. Only one ringing machine was provided—there being no standby machine—which was operated on a start-stop basis and it is a remarkable fact that during the whole of the 17 years service the machine never failed, truly a wonderful performance. The interrupter spring sets on the machine have been changed on very rare occasions. The equipment during the 17 years has given excellent service and complaints from subscribers have been almost negligible.

The passing of an old and trusted exchange is to be regretted and it is only hoped that the new U.A.X. No. 13 equipment will after 17 years have given as good and practically fault free service as did the old village equipment.

The passing of the Hurley and Ramsey village automatic equipment brings to an end the two pioneer exchanges upon which the modern U.A.X. has been developed.

H. M.

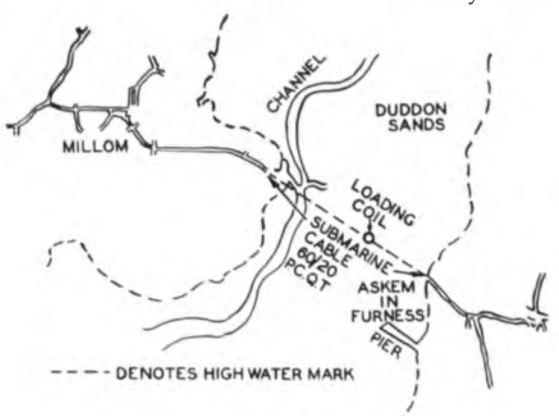
North Western

SUBMARINE CABLE ACROSS THE DUDDON ESTUARY

The closing episode in the engineering work of this District before becoming a Region has been the forging of a link in its main underground system by the submarine cable which now spans the Duddon Estuary between Lancashire and Cumberland.

This 2,940 yard cable has made possible a saving of some 16 miles of duct work, manhole construction and loading coils. The idea of bridging the estuary was conceived in 1936 after the difficulty experienced in maintaining satisfactory circuits between Barrow, Whitehaven and the North. The overhead route was heavy, and ran along undulating and tortuous lanes exposed to wild weather, while the weakest section crossed the Bootle Fells and was inaccessible for long periods at a time. The new cable is a 60 pr/20 star quad with a pure lead sheath of 0.11 inches minimum thickness ; This is rubber sheathed and armoured with 22 No. 2 S.W.G. wires.

In order to maintain 2,000 yard loading spacing a special torpedo type loading pot of 60 coils, 88 mH, with a watertight outer casing, had to be built in the middle of the estuary and subsequently buried in the sands. The cable was made in six lengths, and delivered in two drums to the Askam shore and four to the Millom shore. Shallow waters prevented the use of a proper cable ship, and after the exact lengths had been determined, and two drums of cable on the Askam side actually laid and



jointed, a cable ship had to be improvised and used where the sands and channel were unfit to walk upon, and where it was only possible to approach by means of the water.

The s.s. Jessie owned by the Millom & Askam Iron Co. was hired to assist in this work. The boat had cable drum jacks mounted in the hold and a complete paying-out gear was rigged up in the stern so that the cable could be paid out as the boat crossed the mid channel at high tide.

The shore party for the Millom side was still necessary, and they had to row to the cable ship and use a draw rope to fasten on to the cable end so that it would be pulled ashore.

One of the biggest difficulties was the uncertainty of the height of the tide due to prevailing wind and the short time available before the ships settled on the sand banks.

Some slack in the cable had also to be arranged for, and finally a pontoon had to be used in order to joint the loading coil in mid channel.

Work on the pontoon was very arduous, and the crew did not enjoy their experience of floating in a choppy sea 12 feet deep with no boat near, and when on one occasion the Primus got out of hand, the work seemed very dangerous. " It was a black night with snow and sleet " reports the Clerk of Works. " The pontoon was rocking up and down like a cork in a bottle. It was a job to sit down never mind stand up, and one of the coldest nights I have spent since the War." The icy wind and choppy sea made conditions extremely unsatisfactory.

The various incidents which occurred to several members of the party by treading on shifting sand were treated lightly and with a good deal of humour, and the crossing in the dark of the Kirkby Pool in a small boat which was not quite level will always be remembered by those who took part in this eventful job.

Everywhere the cable was buried to a depth of 14 inches by Siemens Bros. sub-contractors, Messrs. Wimpey of London.

South Western

STORM DAMAGE—JANUARY, 1939

Considerable damage to overhead plant resulted from the severe snowstorm which swept the District on January 25th last. The effects were all the more serious as the routes damaged by a gale some three days earlier were still in many places undergoing repair.

A total of 68 exchanges were isolated, the majority being small exchanges situated on high ground on Dartmoor, Exmoor, The Mendips and similar territory, where many of the roads were blocked for several days due to snow drifts. The photograph indicates typical conditions under which the restoration work had to be undertaken, and the fact that approximately 11,000 subscribers faults and 1,200 trunk and junction faults were cleared in the space of less than a week under such adverse conditions, reflects great credit on the South Western District staff concerned.

RETIREMENT AND DEATH OF MR. J. EMYLN-JONES

Mr. Emlyn-Jones of the District Technical Section retired on December 31st, 1938, after over 43 years in the Telephone Service and died on February 4th, 1939. His early passing came as a painful shock to his many friends who only a month or so previously had made a farewell presentation—contributed to also by personal friends in the Engineer-in-Chief's Office and elsewhere—and had expressed hopes that he would make a good recovery from his recent indisposition and enjoy the pleasures of a long retirement.

Mr. Jones was of a serene and kindly disposition and was a well-known figure in telephone circles in Bristol and the West Country, having joined the National Telephone Co. at Bristol in 1895. A few years later he was concerned in the installation of the Bristol C.B. Exchange—the first such exchange in this country.

He became District Electrician in 1909 and entered the Post Office service on January 1st, 1912, as Chief Inspector in the Bristol Section.

In 1923 he was promoted Assistant Engineer in the Technical Section where, except for a period of loan to Bristol Section, in charge of the auto. conversion, he remained until his retirement.

North Wales

RECONSTRUCTION OF THE MENAI SUSPENSION BRIDGE

The Menai Suspension Bridge, which was built in 1826 by Telford and at its opening was the largest and most important suspension bridge in the world, is now in process of reconstruction to meet modern traffic requirements. The bridge has given yeoman service for over 100 years and has served as the only roadway link between the Isle of Anglesey and the mainland. It carries Watling Street (A.5), the great road which runs from London to Holyhead, across the Menai Straits together with the whole of the telephone and telegraph cables to the Island, thus providing an essential link in the communication between the mainland and Holyhead, and between this country and Eire. Recently by means of these cables a link has been provided between the B.B.C. Welsh Regional Studio at Bangor and their transmitter at Penmon.

The bridge is a beautiful structure and represents a national monument to Telford's genius, and for this reason it is required to carry out the work of reconstruction with as little alteration to its general appearance as possible, and to do the whole work without any interruption to the traffic on this busy road artery.

The centre masonry towers are built on rock and reach to a height of 160 feet above the high water level. The centre span is suspended at a height of 100 feet above sea level and is 580 feet in length. This centre span is suspended from four massive linked wrought iron chains which are anchored in the solid rock beyond each of the approaches to the bridge. In view of the four lines of supporting rods the bridge only carries two lines of traffic with a central footway. The reconstruction proposal is to replace the four wrought iron chains by two similar chains of high tensile steel and so provide for three lines of traffic and remove the speed restriction from traffic (at present 4 m.p.h.). Pedestrians will be provided with cantilever footways supported outside the main bridge. Some details of this difficult engineering problem may be of interest.

The work is anticipated to cost £228,000 and the reconstruction which began in the Autumn of 1938 will extend over 2½ years. Steel superstructure has been erected upon the top of each masonry tower and several steel ropes have been erected over these structures and suspended alongside the existing chains and anchored in deep chambers cut into the rock at each side of each end approach and the anchor supports concreted in. Temporary rods have been bolted to the bridge span and clipped to these temporary steel ropes which at present carry the whole weight of the roadway. The wrought iron chains are now being dismantled with the aid of oxyacetylene apparatus. It is proposed to tunnel out the existing permanent chain anchorages and concrete in the two new high tensile steel chains in place of the two outer wrought iron chains and from these suspend a new central span at about 6 ft. below the present roadway level. The supporting rods will pass through the existing roadway. When this is completed the present deck will be removed in two 580 ft. lengths using the new half of the span for traffic whilst the second half of the present is dismantled. Traffic will pass to the lower level by means of ramps during this stage of the reconstruction work and on removal of the old span the suspension will be tightened to lift the new centre span into the position occupied by the present span. The temporary work will then be removed and the new footways provided by cantilevers projecting outside the present width of the roadway, this will provide a new 23 ft. wide carriageway, with two 5 ft. footways in place of the present two narrow carriageways of 7 ft. 9 in. width.

The present cables required across the Menai Straits are 182 pr/20 Bangor-Holyhead Tk cable, and a 4/40 and 138pr/20 cable for B.B.C. circuits and local junctions and it was soon obvious that these cables could not be maintained uninterrupted across the Suspension Bridge during the extensive reconstruction work. At present

lead-covered cables cross the bridge span in channels provided in the inverted V shaped iron curbs to the carriageway, and at the centre towers flexible joints are provided by V.I.R. tails, and solid plugs. These flexible joints have been found to be very necessary as the centre span of the suspension bridge has considerable movement during rough weather.

It was decided to lay two subaqueous cables across the Menai Straits to take the above circuits and these cables were laid in December last at a position approximately 100 yards north of the suspension bridge. The cables were laid by the local staff under the supervision of the Assistant Submarine Superintendent (Mr. Leach) and assisted by seamen of H.M.T.S. Alert under the control of the 2nd Officer (Mr. Jago).

The length of submarine cable concerned was 433 yards and this included end sections of 98 yards to connect with manholes on the existing tracks.

Arrangements were made to hire a large flat bottomed sea barge and the cable was coiled in large loops at the barge bottom and supported on staging made of recovered telegraph poles. This was done at Caernarvon, the cable being unwound from drums jacked up on the harbour. The barge was towed to the suspension bridge and sufficient slack cable fleeted ashore to make up the shore end on the Welsh side ; this was securely anchored just above high water mark by bars driven into the shore and also secured by lashing and blocks and tackle. The cable end passed over the stern of the barge via a "cable brake," which consisted of three circular wooden annular rings supported on pillars and on a solid framework. Two of the rings had horizontal cuts across them and attached to the upper half of the ring was a 6-ft. lever which could be moved to enlarge or contract the hole contained by the two portions of the ring. The cable passed through the centre of these rings and the levers could be operated to exert pressure on the armoured sheath and so control its rate of progress of passing from the barge to the sea bottom.

A few minutes before the time of high tide, a high powered motor boat was sent across from the barge to the Anglesey shore towing a slack 3-in. hawser; the end of the hawser was made fast to an eye bolt fixed in the rock on the Anglesey shore. The donkey engine and windlass on the barge then wound in the slack of the rope and the motor boat returned to the barge and fixed a tow rope from its stern to the prow of the barge. Another powerful motor boat was lashed fore and aft to the barge and at high tide the motor boats commenced to pull the cable barge across the Straits, the motor boat at the fore being used mainly for steering. The donkey engine wound in the 3-in. hawser, which was employed mainly as a reserve means of haulage in case of engine failure of the motor boats. The starting of the motor boats was a signal for the six men in the hold to pay out the loops of cable which entered the water at the stern, via the "cable brake," the latter being manned by two seamen. By this means the course of the cable was kept in a direct line, and the cable laid at a fairly rapid speed, the time for the 325 yard crossing being 7 minutes.

On the Anglesey side a gang of 25 men lifted the cable end ashore on the quay where it was left anchored and coiled prior to fleeting up of the shore end on the following day. The shore ends were buried in trenches previously channelled out. Owing to the special nature of the tides and the necessity for carrying out the work at slack tide, it was necessary to lay each cable on separate days, the time of slack tide being approximately 15 minutes. Efficient use of this time was only possible by careful organisation in advance.

The tide race is very swift at this narrowest portion of the Menai Straits and two opposite tides meet at about this point; it was, therefore, considered necessary to anchor the cables to prevent subsequent movement by the tides. For this purpose a deep sea diver was employed to place bags of wet concrete on the cable. The diver was able to descend only for maximum periods of ½ hour at slack tide at low water each day and his operations extended over a period of three weeks. Bags of concrete were laid on the cables at 10 ft. intervals and in three portions of the length it was necessary for the diver to build 5-ft. pillars to carry the cable over ledges. The diver stated that the floor of the Straits resembled a quarry and the current was so fast that it prevented the accumulation of any weed or debris. The depth at the centre of the Straits at this point is approximately 40 ft. On completion of the work the diver broadcast his experiences from the Welsh Regional Studio and his words passed along the cables on which he had been operating. The submarine sections of the cables have now been brought into service and should meet all requirements until the new bridge is completed. Six ways are being provided in the reconstructed bridge for P.O. cables.

H. J.

Staff Changes

Promotions.

Name	District	Date
From Exec. Engr. to A.S.E.		
Carter, F. C.	E.-in-C.O.	1.4.39
From Chief Insp. to Asst. Engr.		
Greene, A. H.	N.E. Reg.	5.1.39
Dore, L. J.	N. Wales	15.1.39
Hobbs, H.	S. Western	22.1.39
From Chief Insp. to Chief Insp. with allowance		
Bines, H. T.	L.T. Reg.	21.1.39
Howe, H. B.	L.T. Reg.	1.1.39
From Insp. to Chief Insp.		
Sutherland, J. C. C.	Leafield R/S to Cupar R/S	To be fixed later
Barnes, T. C.	L.P. Reg.	do.
Luck, L. A.	S. Mid. to S.W.	do.
Dunkley, L. W.	N. Midland	20.2.39
Crossley, J.	E.-in-C.O.	9.11.38
Coulman, A. H.	E.-in-C.O. to S.W.	22.2.39
Perkins, J. J.	E.-in-C.O.	29.11.38
Wheatley, S. J.	Test Secn. Ldn.	To be fixed later
Winter, F.	Eastern	do.
Humphreys, H. L.	L.T. Reg.	1.1.39
Worth, W. B.	L.T. Reg.	21.1.39
Hutchings, W. S.	L.T. Reg.	14.12.38
Kingham, M. W. E.	E.-in-C.O. to S. Mid.	22.1.39
New, S. E.	L.T.R. to S. Wa.	1.2.39
Moxon, T.	N. Wa. to Sc. R.	18.12.38
Lowther, S. W.	S. Western	22.1.39
Sawyer, T. H. E.	L.T. Reg.	To be fixed later
Padgham, F. V.	E.-in-C.O.	13.10.38
Richards, B.	N. Wales	15.1.39
Coulson, J. N.	S. Lancs	2.2.39
From S.W.I. to Insp.		
Nolan, F. M. A.	S. Wales	23.10.38
Huckfield, F. E.	S. Wales	28.5.38
Jones, W. H.	S. Wales	23.10.38
Kirby, H. V.	S. Wales	17.12.38
Rafferty, J. S.	S. Wales	26.6.38
Harding, C. C.	S. Wales	19.6.38
Huckfield, H.	S. Wales	10.12.38
Griffiths, H.	S. Wales	19.4.38
Clarke, C. J. T.	S. Wales	21.8.38
Corp, B.	S. Wales	28.10.30
Almond, C. H. R.	Eastern	10.11.38
Rust'D'Eye, E. A.	Eastern	29.1.39
Smith, A. T.	Eastern	12.1.39
Firman, S. B.	Eastern	4.12.38
Topsfield	Eastern	12.11.38
Allbon, G. E.	Eastern	14.11.38
Stooke, G. H.	N. Wales	26.7.38
Chatfield, R. A.	N. Wales	1.9.38
Luff, E. C.	S. Midland	22.1.39
Granger, E. H.	S. Midland	12.2.39
Evans, F. G.	S. Midland	12.2.39
Weller, E. H.	S. Midland	22.1.39
Horton, E. B.	S. Midland	11.9.38
Jennings, L. T.	S. Midland	12.2.39
Fidler, C. H.	S. Midland	21.2.39
Griffin, W. J.	T.S. B'm. to T.S. Ldn.	7.12.38
Early, W. F. L.	T.S. B'm. to T.S. Ldn.	7.8.38
Allibone, G.	T.S. B'm. to T.S. Ldn.	1.1.39
Goldsmith, F.	L.T. Reg.	6.12.38
Bennett, F. G.	L.T. Reg.	6.12.38
Bowler, T. R.	L.T. Reg.	6.12.38
Jones, H. G.	L.T. Reg.	6.12.38
Hawkins, W. J.	L.T. Reg.	6.12.38
Slade, H. C.	L.T. Reg.	6.12.38
Freeman, C. A.	L.T. Reg.	6.12.38
Clarke, R. W.	L.T. Reg.	6.12.38
Webb, J. A. G.	L.T. Reg.	6.12.38
Jones, W. A.	L.T. Reg.	6.12.38
Fife, A.	L.T. Reg.	6.12.38
Flegg, H. L.	L.T. Reg.	6.12.38
Roberts, W. A.	L.T. Reg.	6.12.38
Robinson, F. S. P.	N. Midland	28.8.38
Miller, J. W.	N. Midland	1.1.39
Shuff, R. T.	N. Midland	1.1.39
Williams, R. V.	N. Midland	7.12.38
Rawbone, K. F.	N. Midland	1.1.39
Denman, J. H.	S. Lancs	1.11.37
Games, A. V.	S. Wales	1.10.38
Westcott, A. J. L.	L.T. Reg.	To be fixed later
Beaumont, J. W.	L.T. Reg.	do.
Michie, P.	Scot. Reg.	18.9.38
Sinclair, C.	Scot. Reg.	31.7.38
Lawson, J. P. S.	Scot. Reg.	30.10.38
Rae, J.	Scot. Reg.	1.9.38
Lanfear, E. T.	S. Western	26.1.39
McCormick, A.	N. Ireland	5.2.39
From Second Officer to Chief Officer		
Wallis, R. H. J.	H.M.T.S. Monarch	30.12.38
From Third Officer to Second Officer		
Troops, A. E.	H.M.T.S. Monarch	30.12.38
From Fourth Officer to Third Officer		
Oates, J. G. B.	H.M.T.S. Alert to H.M.T.S. Monarch	To be fixed later

Transfers.

Name	District	Date
A.S.E.		
Gregory, H. J.	S.E. to E.-in-C.O.	1.1.39
Exec. Engr.		
Taylor, T. A.	E.-in-C.O. to S. Mid.	1.1.39
Asst. Engr.		
Reed, R. E.	N.E.R. to S.Wa.	18.12.38
Cain, S. J.	N.W. to S. Mid.	5.2.29
Insp.		
Moxon, T.	N. Wa. to Sc. R.	18.12.38

Retirements.

Name	District	Date	Name	District	Date
A.S.E.			*Chief Insp.*		
Francis, E. S.	.. S. Midland	31.12.38	Myers, W. H.	.. S. Lancs	31.12.38
Blight, W. O.	.. E.-in-C.O.	31.12.38	Crowther, H. W.	.. N.E. Reg.	31.3.39
Exec. Engr.			*Insp.*		
Armitage, D. ..	.. E.-in-C.O.	30.9.38	Bowie, W. A.	.. Scot. Reg.	31.12.38
Hill, S. F. ..	.. N. Wales	31.12.38	Hook, H. G. ..	.. S. Midland	31.12.38
Payton, G. A.	.. E.-in-C.O.	3.1.39	Maggs, J. ..	.. S. Midland	31.12.38
Asst. Engr.			Mabbutt, E. ..	.. L.T. Reg.	1.1.39
McCahey, R. T.	.. S. Western	31.12.38	Webb, A. J. D.	.. L.T. Reg.	31.12.38
Emlyn-Jones, J.	.. S. Western	31.12.38	Cleary, F. A. ..	.. L.T. Reg.	23.12.38
Gaskins, F. W.	.. N.E. Reg.	31.1.39	Smith, A. ..	.. Test Secn. B'm.	31.12.38
Chief Insp. with allowance			Warburton, T. E.	.. S. Lancs	31.1.39
McLennan, J. A.	.. L.T Reg.	31.12.38	Hammond, A. E.	.. L.T. Reg.	31.1.39
			Phipps, A. ..	.. S. Midland	20.2.39
			Awcock, P. W. J.	.. S. Eastern	27.2.39

Deaths.

Name	District	Date	Name	District	Date
Chief Insp.			*Insp.*		
Ridd, J. E. ..	.. S. Wales	27.12.38	May, E. ..	.. S. Western	26.11.38
Evennett, W. J.	.. L. T. Reg.	5.12.38	Rees, J. W. ..	.. S. Wales	2.1.39
			Hewitt, B. ..	.. N.E. Reg.	2.2.39
			Mathew, P. R.	.. Scot. Reg.	1.2.39

Secondments.

Name	District	Date	Name	District	Date
Asst. Engr.					
Turner, H. A.	.. E.-in-C.O. to S.F.E.R.T., Paris	24.1.39			

Communications

All Communications should be addressed to the Managing Editor, *P.O.E.E. Journal*, Engineer-in-Chief's Office, Alder House, Aldersgate Street, London, E.C.1. Telephone: NATional 6321. Remittances should be made payable to "*The P.O.E.E. Journal*" and should be crossed "& Co."

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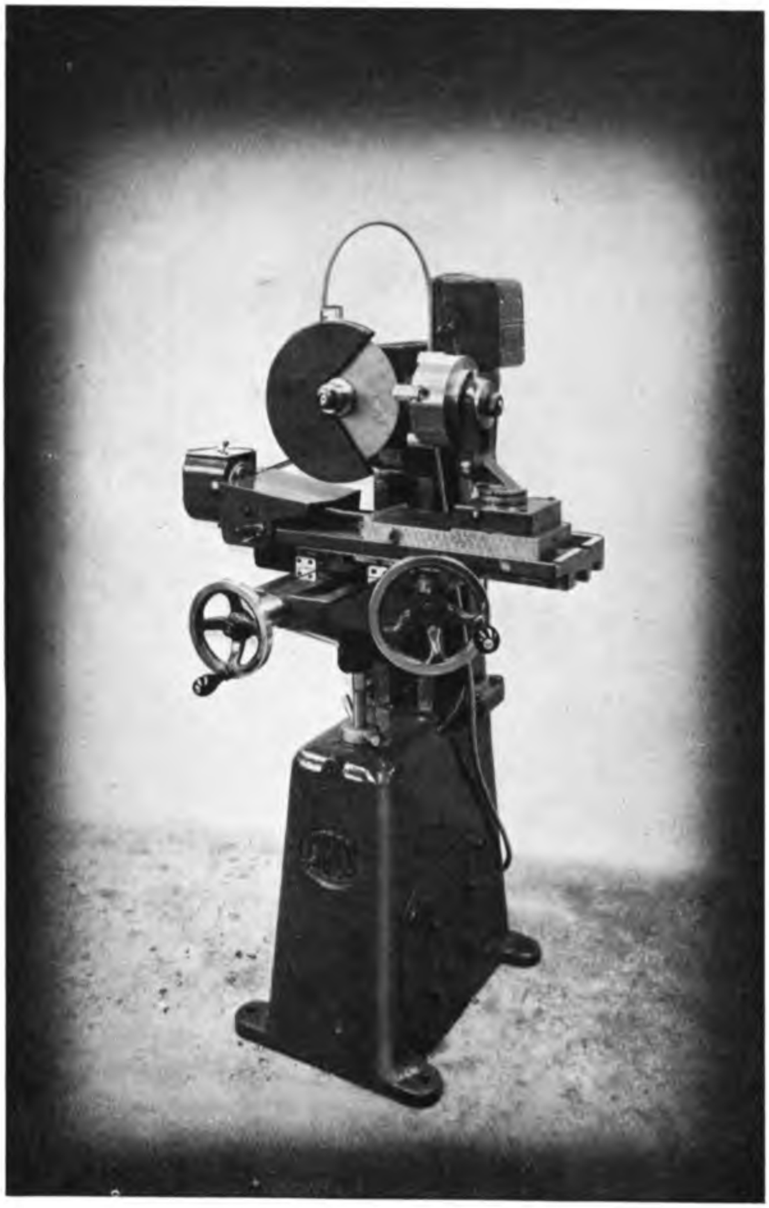

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