THE POST OFFICE ELECTRICAL ENGINEERS' JOURNAL

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THE INSTITUTION OF POST OFFICE ELECTRICAL ENGINEERS

THE POST OFFICE ELECTRICAL ENGINEERS' JOURNAL

Vol. XXXIX January, 1947 Part 4

H.M.T.S. Monarch

A. J. GILL, B.Sc., M.I.E.E., F.I.R.E.

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The author gives a general description of the building of the largest and most modern addition to the Post Office fleet of cable ships, H.M.T.S. " Monarch." The " Monarch " differs in shape and size from any other previous ship and contains many novel features in its equipment, including electric drive for the cable machinery.

Introduction.

IN the April 1946 issue of this JOURNAL mention was made of the new Post Office cable ship H.M.T.S. *Monarch*, and articles about it have also appeared in the daily and technical press. Some description of the ship and its equipment will doubtless be of interest to readers of the JOURNAL.

This ship (Fig. 1) is very much larger than any previous Post Office cable ship, all of which have been relatively small vessels of the order of 1,000 tons, and designed to carry out repairs and to lay short lengths of cable in home waters. *Monarch*, on the other hand, is the largest cable ship in the world, with a gross tonnage of 8,056 and a loaded displacement of 14,000 tons.

This expansion of the Post Office cable fleet is due to the fact that in March, 1941, the only large British owned cable ship, the *Faraday*, owned by Messrs. Siemens Bros., was destroyed by enemy action, and the Government decided that there was a national need for such a vessel, and that a new ship should be provided by the Post Office. The new ship was intended for war purposes, but pressure on shipbuilding capacity as a result of losses due to enemy submarines led to its postponement and, although the design was completed in 1942, actual construction was not started until late in 1944. She was launched on August 8th, 1945, and underwent her shipbuilder's trials in February, 1946.

She was built at their Neptune Yard, Walker-on-Tyne, by Messrs. Swan, Hunter and Wigham Richardson Ltd., a world-famous firm, builders of the famous *Mauretania*, which held the blue ribbon of the Atlantic for 25 years. Messrs. Swan, Hunter and Wigham Richardson have built more cable ships than any other firm in the world. The ship has been built under the special survey, and in accordance

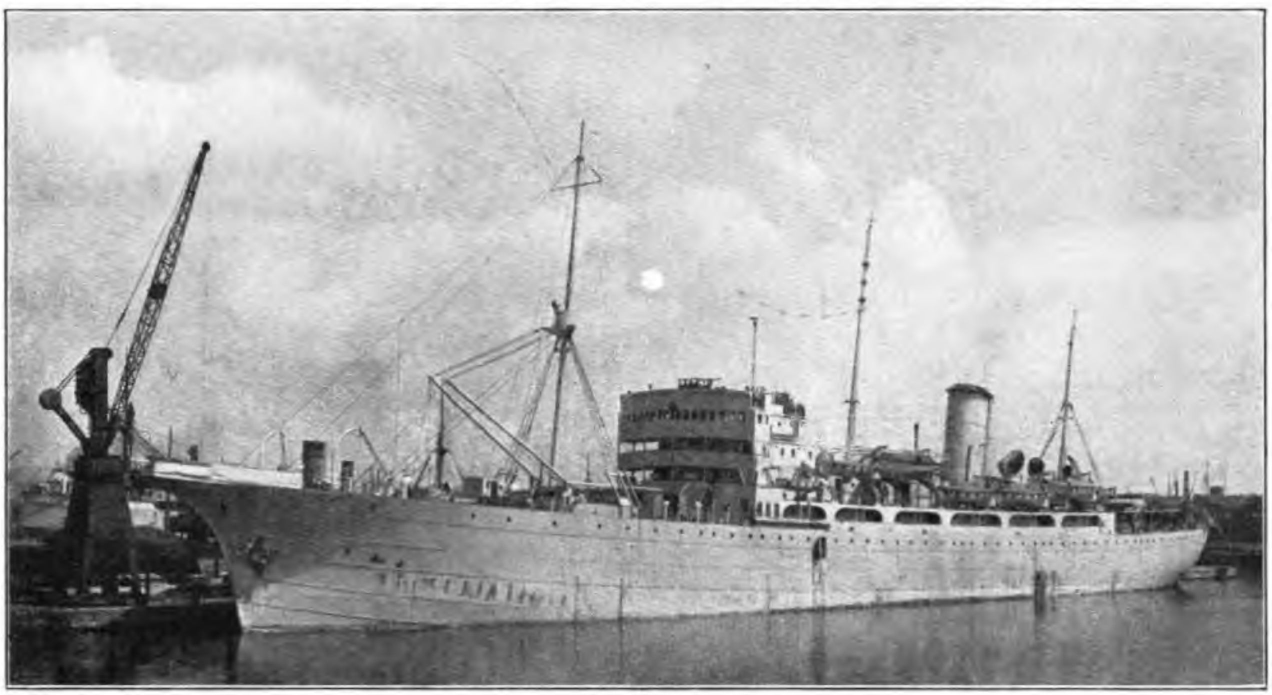


FIG. 1.—H.M. TELEGRAPH SHIP " MONARCH."

with the requirements of Lloyds Register of Shipping, for their Class ✠ 100 A.1., "with freeboard."

Specification.

Arranging for the construction of a large ship like this is a little outside the normal run of P.O. engineers' work and some description of this procedure may be of interest. First, it was necessary to decide upon the carrying capacity of the vessel and the maximum speed as these factors would decide her size, shape and power required. This was provisionally fixed between 5,000 and 6,000 tons of cable and a half load speed of 14½ knots for propulsion. The next step was to settle on the type of propelling machinery to be used.

The requirements of a large cable ship are peculiar in this respect. As she is mainly required for laying new cables or for deep sea repairs she will have substantial periods in port. Moreover, when at sea, while laying cable her speed will be low, say, 6 to 7 knots, and when picking up cable still less. In addition, there will be periods when she is practically motionless, i.e., when jointing and grappling. On the other hand, it is desirable that she should be capable of a fair turn of speed to enable her to get to and away from the scene of operations quickly. Thus, an undue expenditure to attain very high thermal efficiency is unlikely to be repaid by saving in fuel costs. On the other hand, the highest degree of manœuvrability is required and her engines must be capable of running astern at full power for prolonged periods. This ruled out direct Diesel or steam turbine drive and the issue then lay between steam reciprocators, turbo-electric or Diesel electric. Either of the electric drives would have been appreciably more costly than the reciprocator although offering some advantage in overall efficiency. Electric drive was less certain from the delivery aspect and after careful consideration it was decided to adopt triple expansion engines driving twin screws with oil-fired Scotch boilers.

After preliminary discussions with the shipbuilders a draft specification was prepared by the Post Office, giving the approximate dimensions of the vessel, the detailed requirements of the plant and accommodation to be provided to enable the builders to get out general arrangement drawings. As soon as possible the builders prepared drawings of the proposed hull shape and these were sent to the National Physical Laboratory where a wax model of the ship's hull was made and tested in the experimental tank to ascertain the force required for propulsion.

The next step was for the engineers to produce designs for the propellers, from which scale models were made by the Laboratory and fitted to the wax model, which was then provided with electric motors and driven through the water at the scale speed. The thrust of the propellers was recorded to confirm that the hull shape, the propeller shape and the computed power required were likely to meet requirements on the actual vessel.

Meanwhile, the builders had examined the Post Office specification and had replied with an amended one detailing their proposals. After further discussions the final specification was agreed and signed together with agreed general arrangement drawings of the ship.

Construction.

Monarch is quite different in size and shape from any previous vessel and the amount of detailed design and entirely novel work necessary on the part of the builders is astonishing in contrast to telecommunications projects involving quantity production.

One of the first jobs in actual construction is the preparation of full size drawings of each of the ship's frames or "ribs" on a large floor called the moulding loft. From these drawings wooden templates (or patterns) are prepared and used to check the shaping of the actual frames which are bent red hot on a cast iron floor by portable hydraulic rams. On each side of the *Monarch* there are over 180 of these frames, no two of which are alike, of 10 in. × 3½ in. bulb angle steel sections. While this work is going on the shipwrights are preparing the wooden blocks on which the keel plates are laid and on which the ship is supported during the process of building and until just prior to launching when the weight is transferred to the cradle and slipway. The frames are now placed above the keel and around them is built up the double bottom which is practically a large flat tank about 6 ft. deep the length and width of the ship and divided into sections. On the frames are then fitted the hull plating. Fig. 2.

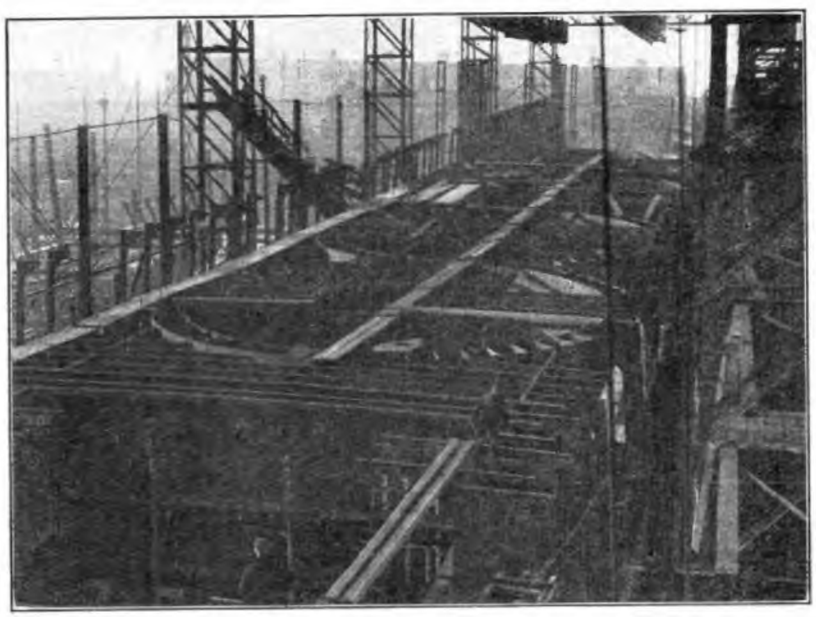


Fig. 2.—Framing, showing Cable Tanks and Cofferdam.

On *Monarch* the vertical joints in the plates are flush welded by the electric arc process whereas the horizontal joints are lap riveted. This lessens the risk of stress as compared with an all-welded job and produces a pleasing appearance as the ship's lines are indicated by the visible strakes without interruption due to vertical joints. As the hull approaches completion arrangements are made to build the slipway and cradle. The slipway consists firstly of the fixed or standing ways which are two timber tracks each about 3 ft. wide, spaced about 30 ft. apart and laid on a slope of about ⅝ in. to a foot extending the whole length of the ship and down to the level of water at low tide. These constitute tracks down which the ship slides. On these are placed the sliding ways which are like huge sledge runners. Lubrication such as soft soap, tallow, etc. is placed between the fixed and moving ways. On the moving ways is built up the cradle, a mass of timber bolted together which is finally wedged up under the ship to support its weight a short time before it is due for launching.

When a ship is launched the stern enters the water first and at a certain stage the rear portion of the vessel becomes water borne while the bow is still on the cradle. As the stern rises, more and more load is placed on the foremost portion of the cradle known as the forward poppet. This is quite a critical condition as any miscalculation or bad workmanship might mean that the vessel came off the cradle on to the ground and broke its back. To the credit of British shipbuilders it can be stated that such a happening has been extremely rare.

Monarch, like most ships, was launched before the engines were installed and the weight of the hull at launching was between 4,000 and 5,000 tons. Although this was small compared with huge ships such as the *Queen Elizabeth* yet she looked quite impressive and made a graceful curtsey as the forward-poppet came off the slipway and she took the water, Fig. 3. The launching ceremony was carried out by Lady Gardiner in the presence of the Postmaster General and Sir Thomas Gardiner; Sir Philip Wigham Richardson, Chairman of the Company; the late Mr. T. Morison, director; Admiral Morgan, Director of Signals, Admiralty; and many others.

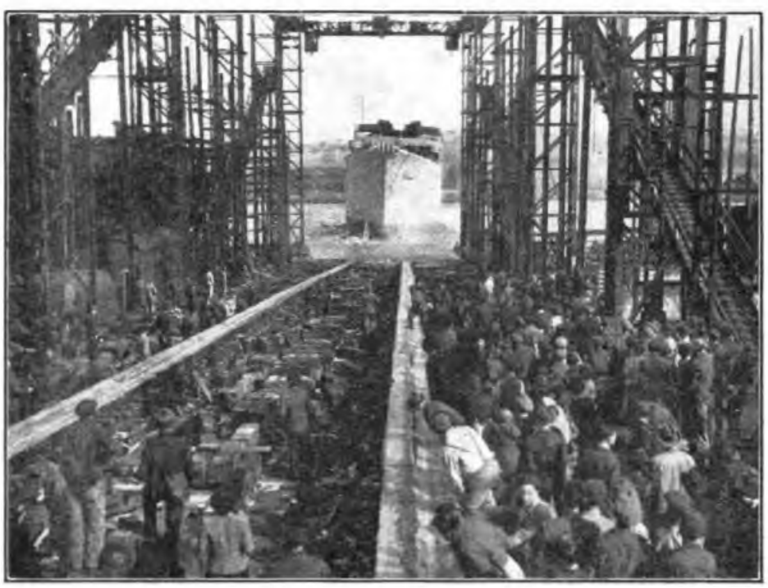


Fig. 3.—The Launching.

Layout.

The overall length of *Monarch* over the bow and stern sheaves is 475 ft., the length between perpendiculars 435 ft., the breadth 55 ft. 6 in. and draught when loaded 27 ft. 10 in. Her total deadweight (i.e. the maximum load she can carry consisting of cargo, fuel and stores) is 8,950 tons. The total cable tank capacity is 170,000 cubic ft. of which 125,000 cubic ft. is available for coiling in four tanks each 41 ft. in diameter. Oil bunker capacity is 2,000 tons and fresh water and feed water capacity 400 tons each.

The guaranteed speed was 14½ knots with a deadweight of 4,250 tons and this was readily achieved on trial.

As will be seen from Fig. 4 the ship has an overhanging stem carrying three cable sheaves and a cruiser stern with a single sheave on the port side. The main and shelter decks run the full length of the ship with a boat deck amidships surmounted at the forward end by the Captain's bridge deck and navigating bridge.

The cellular double bottom runs almost the full length of the ship and is subdivided to carry feed water, water ballast, Diesel oil and fuel oil. In addition there are a number of other tanks for water ballast, fresh water and oil fuel, distributed throughout the ship.

The propelling machinery is situated aft of the four cable tanks, forward of which is a large hold for cable buoys, ropes, etc. A cofferdam is provided between the cable tanks and oil fuel bunkers. The dynamo room is separate from the engine room from which it is entered through a watertight door, seen in the background of Fig. 5. There is also an escape and ventilating shaft to the main and shelter decks.

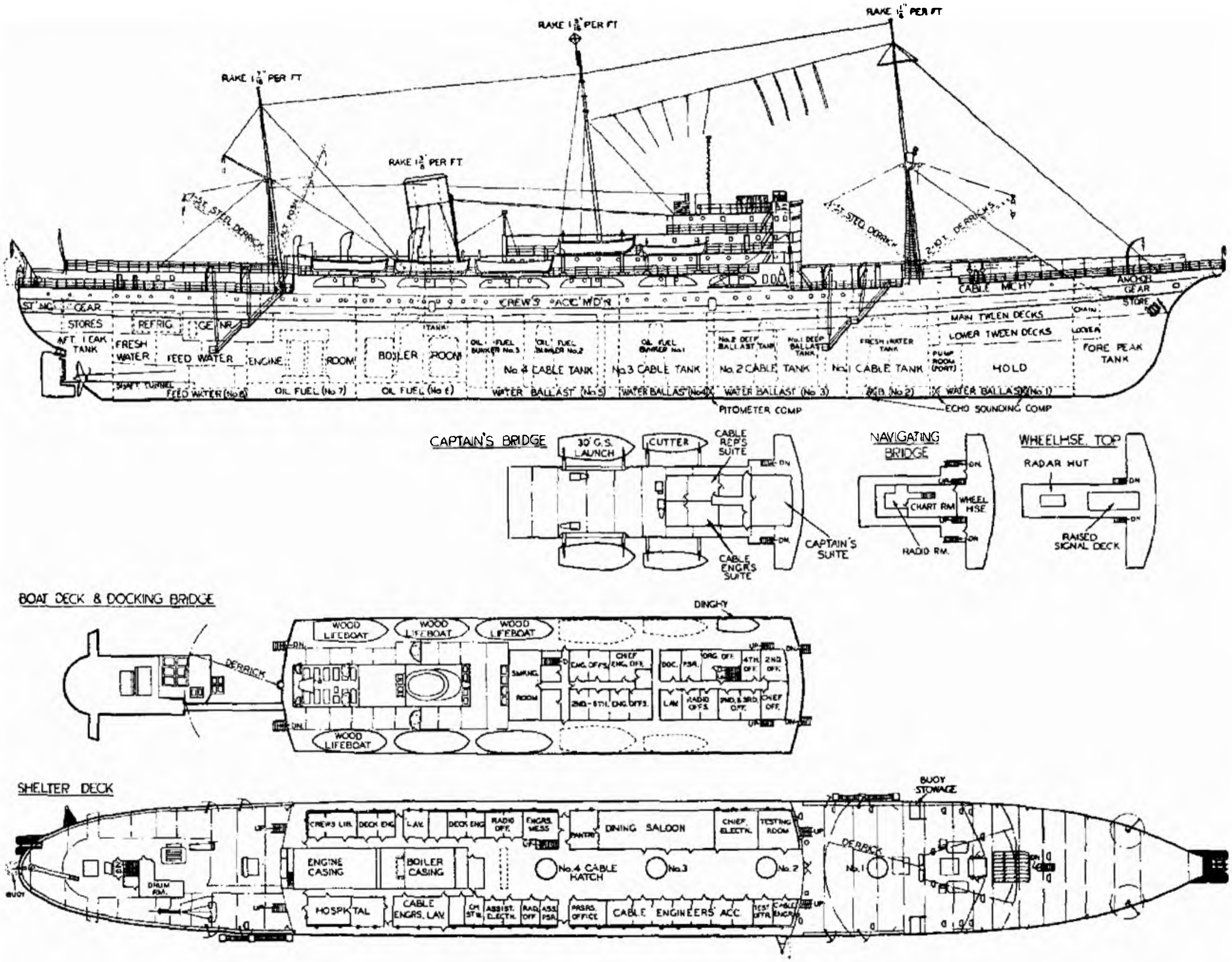
The main deck amidships is devoted to the men's quarters with the steering flat right aft. On this deck forward are the two forward cable engines and the windlass together with stores and workshops.

The shelter deck immediately above the main deck contains officers' cabins, the cable testing room, the hospital and surgery and the dining saloon and sundry offices.

Three steel masts are fitted. The foremast carries two derricks each for a lift of 10 tons on the forward side and a single derrick for 5 tons on the after side. The mizzen mast has a single derrick for 5 tons lift and can be interchanged fore or aft. The main mast carries the wireless aerials and direction-finding loops.

Exposed decks are sheathed with teak and the enclosed working spaces on the shelter deck are sheathed in Oregon pine.

The accommodation for the crew is in



RAKE $1\frac{1}{16}$" PER FT
RAKE $1\frac{3}{16}$" PER FT
RAKE $1\frac{1}{8}$" PER FT
RAKE $1\frac{3}{8}$" PER FT
STEEL DERRICK
STEEL DERRICK
DERRICKS
CREW'S ACC'M'D'N
ST'NG GEAR
STORES
REFRIG
AFT LEAK TANK
FRESH WATER
FEED WATER
ENGINE ROOM
BOILER ROOM
SHAFT TUNNEL
FEED WATER (No 8)
OIL FUEL (No 7)
OIL FUEL (No 6)
No 4 CABLE TANK
No 3 CABLE TANK
No 2 CABLE TANK
No 1 CABLE TANK
WATER BALLAST (No 5)
WATER BALLAST (No 4)
WATER BALLAST (No 3)
WATER BALLAST (No 1)
No 2 DEEP BALLAST TANK
No 1 DEEP BALLAST TANK
FRESH WATER TANK
PUMP ROOM (PORT)
HOLD
CABLE MCH'Y
MAIN TWEEN DECKS
LOWER TWEEN DECKS
ANCHOR GEAR
STORE
CHAIN LOCKER
FORE PEAK TANK
PITOMETER COMP
ECHO SOUNDING COMP
CAPTAIN'S BRIDGE
30' G.S. LAUNCH
CUTTER
CABLE REP'S SUITE
CAPTAIN'S SUITE
CABLE ENGRS SUITE
NAVIGATING BRIDGE
CHART RM
WHEEL HSE
RADIO RM.
WHEELHSE. TOP
RADAR HUT
RAISED SIGNAL DECK
BOAT DECK & DOCKING BRIDGE
DINGHY
WOOD LIFEBOAT
WOOD LIFEBOAT
WOOD LIFEBOAT
WOOD LIFEBOAT
DERRICK
SMK'NG. ROOM
CHIEF ENG. OFF.
DOC.
PSR.
4TH OFF.
2ND OFF.
LAV.
RADIO OFFS.
2ND & 3RD OFF.
CHIEF OFF.
SHELTER DECK
BUOY STOWAGE
CREW'S LIB.
DECK ENG.
LAV.
DECK ENG
RADIO OFF.
ENGRS. MESS
PANTRY
DINING SALOON
CHIEF ELECTN.
TESTING ROOM
DERRICK
ENGINE CASING
BOILER CASING
No.4 CABLE HATCH
No.3
No.2
No.1
DRUM RM.
BUOY
HOSPITAL
CABLE ENGRS. LAV.
ASSIST. ELECTN.
RAD. OFF
PSRS. OFFICE
CABLE ENGINEERS' ACC
TEST OFFR.

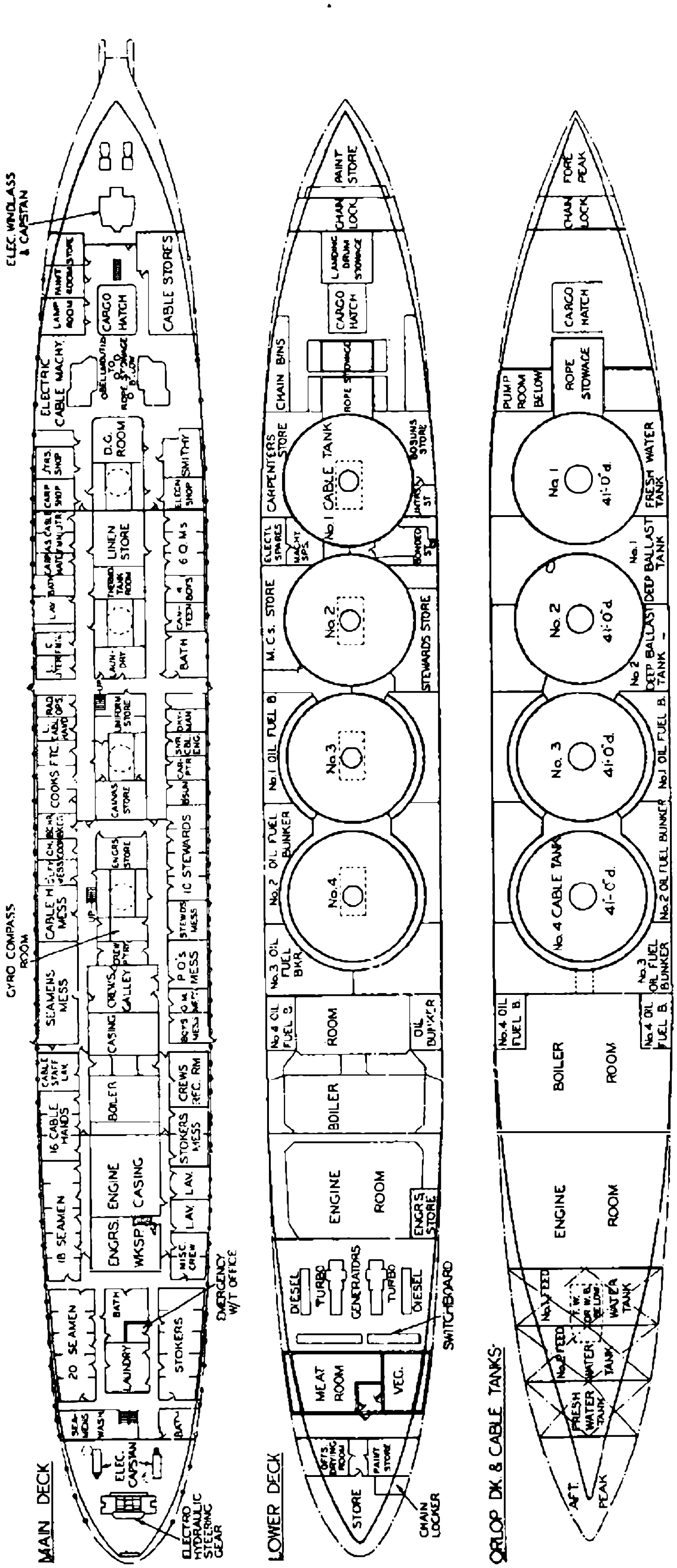


FIG. 4. H.M.T.S. MONARCH. GENERAL ARRANGEMENT. (SCALE 1"=56')

accordance with modern standards. Mechanical ventilation and heating is installed throughout the ship. The officers' saloon will accommodate forty; in addition a small mess is provided for engineers coming off shift. Petty Officers are berthed two in a cabin and in no room are there more than four men. A crew's recreation room, writing room, library and canteen are provided. The Captain's suite comprises a large day room, bedroom and private bathroom and on the same deck house are suites for the cable representative and cable engineer.

Monarch is well equipped with boats. First of all there are six 30 ft. lifeboats in accordance with statutory requirements, one of which is fitted with a motor, providing accommodation for the whole crew in the three boats on either side of the ship. In addition there are five boats for cable work consisting of two 30 ft. general service launches fitted with V 8-cylinder engines, two 26 ft. cutters and one 16 ft. dinghy fitted with outboard engine. The launches and cutters are carried on gravity davits.

At the forward end of the shelter deck are the cable engine controls, the forward drum room, dynamo-meters, bow sheaves and working spaces. Aft of the accommodation on the shelter deck is the after drum room, the after paying-out machine, stern sheave and taut wire gear.

On the boat deck, which is connected aft to the docking bridge, are cabins for the senior navigating and engineer officers, the purser and surgeon, together with a smoking room. The captain's suite and two suites for the chief cable engineer and cable representative are above the boat deck and immediately below the bridge, chart room and wireless room. The bridge extends over the whole width of the ship and is totally enclosed. Four clear view windows are provided. The engine room and cable telegraphs are of Siemens' electric type and the engine revolution telegraphs are of Chadburn's Navy type. Siemens' electric helm indicators and Record electric engine revolution indicators are fitted. An electrical device for giving periodic whistle signals during fog is provided.

For measurement of the ship's speed and distance travelled relative to the water, a Pitometer equipment is fitted together with repeater dials in the engine room and after drum room. The system depends for its operation on the difference in pressure produced by the ship's motion between two orifices in a fitting projecting some distance below the bottom of the

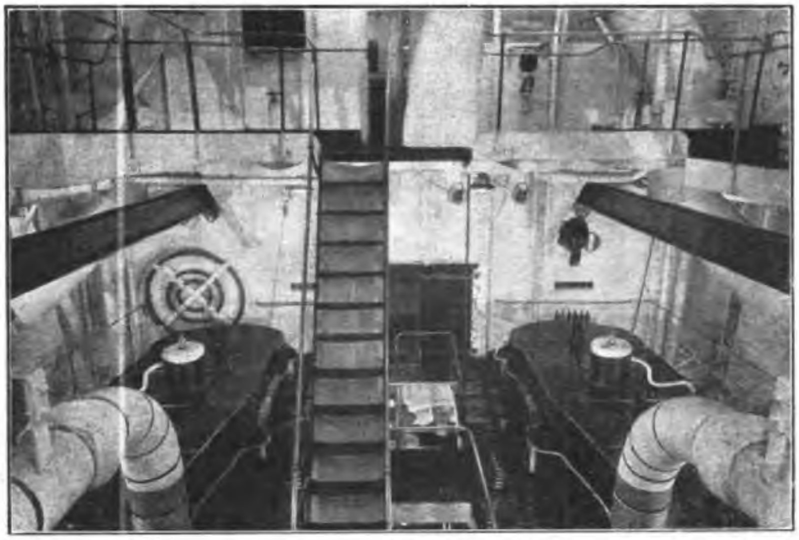


FIG. 5.—ENGINE ROOM—TOP PORTION.

ship. This installation is also provided with a graphic speed recorder.

The steering gear is of the electric hydraulic four ram type controlled from the bridge by telemotor gear. In addition Sperry hand and automatic electric steering is provided. The Sperry master compass is housed in a special room on the main deck with repeaters on the bridge, bow sheaves, after steering station and after sheaves.

The vessel is provided with means whereby the helm and engine can be controlled from the bow or stern through telegraphs.

Propelling and Auxiliary Machinery.

The main propelling engines are 21 in., 35 in., and 60 in. diameter respectively for h.p., i.p. and l.p. cylinders with a common stroke of 39 in. and they develop about 4,500 h.p. at 110 r.p.m. The crankshafts are of the built-up type and each consists of three similar sections bolted together. Fig. 5 shows the top of the engine room, some idea of size is given by the piston rings—largest 5 ft. diameter—on the bulkhead. Michell thrust blocks are fitted. There are four main boilers 15 ft. diameter, 11 ft. 6 in. long and working at 220 lb./in.^{2} and a Cochran vertical boiler working at 110 lb./in.^{2} is fitted for heating purposes in port. All boilers are oil fired on White's system. Separate condensers having a cooling surface of 3,000 sq. ft. designed to provide a vacuum of 27 in. Hg. (30 in. barometer) in tropical waters are fitted. Independent air pumps and circulating pumps are provided for each set of engines.

Most of the auxiliaries are steam driven although electric fresh water and sanitary pumps are also provided and an electric submersible pump is fitted in the boiler room. Electric turning gear is provided on the main engines. Howden's system of forced draught is provided, two engines being provided each capable of driving the fan. In other respects the propelling and auxiliary machinery follows standard practice.

Monarch is different from all previous cable ships in having electrically driven cable engines. The advantage of electrical drive is that if the deck machinery is also electrically driven it is possible to avoid running high pressure steam pipes and exhaust pipes throughout the accommodation. This conduces to the comfort of the crew when in the tropics and removes a source of danger in war time. Moreover it avoids all danger from frost and also the serious condensation losses which normally occur in keeping steam engines ready for instant use. On the other hand, however, the steam engine has characteristics for haulage work which it is difficult to provide with normal types of electric motors. Steam engines used for this work are normally three crank double acting simple engines having six working strokes per revolution, giving a very even torque variable from zero to full load. If the load happens to be greater than the engine torque or if the brake is applied, the engine merely stalls and takes up again if more steam is applied or if the load falls. To provide these characteristics with electric motors involves the special gear mentioned below.

There are three electrically driven cable engines on the *Monarch*—two machines for paying-out and picking up, placed on the main deck forward, Fig. 6, and a paying-out machine on the shelter deck aft,

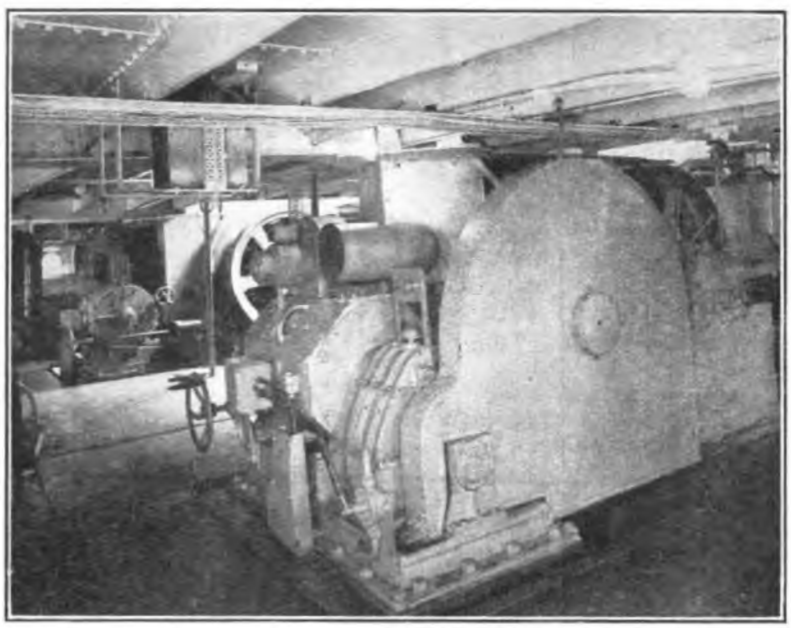


FIG. 6.—CABLE ENGINES FORWARD.

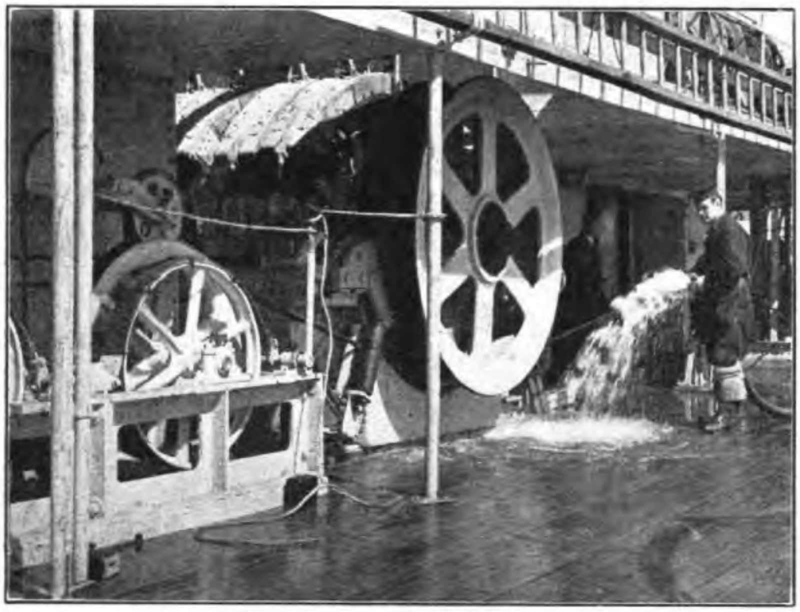


Fig. 7.—Cable Engines Aft.

one or, if necessary, two dynamos in series. These dynamos are identical and interchangeable with machines used for lighting, but when used for constant current work they are separately excited from a special machine known as an amplidyne, one of which is seen in the foreground Fig. **8**. This is a D.C. generator having two poles and two pairs of brushes at 90° to each other; one pair is short-circuited. A small current in the control field winding produces a heavy current in the armature through the short-circuited brushes. This heavy current gives rise to a powerful armature reaction field at right angles to the original field which, in turn, produces an output voltage at the second pair of brushes. In effect the machine is a powerful and quickly responsive D.C. amplifier having a gain of about 40 db. (i.e. a power amplification of 10,000 times). Thus 1 milliwatt will produce an output of 10 kW in 0·1 second. The amplidyne which is driven by a 220 volt motor controls the excitation of the main generator or generators so that the current never falls below 295 amperes or rises above 305 amperes although the voltage generated may vary from 10 volts to 700 volts. This current passes in turn through the armatures of the motors which are all in series. The field magnets of the motors are excited from the ordinary 220 volt constant voltage supply used for lighting. With no field a motor has no tendency to turn in spite of the 300 amperes flowing through the armature. When a current is supplied to the field windings the motor immediately exerts a torque or turning effort proportional to the applied field. If the turning effort is insufficient to move the load nothing happens; the motor is stalled and continues to exert an effort and can continue to do so indefinitely without risk of damage. If the field excitation is increased sufficiently

Fig. 7. For paying out long deep sea cables the after machine would be used whereas, for laying in shallow water or for picking up in any depth of water, the forward machines would be used. These machines and associated gear were supplied by the Telegraph Construction & Maintenance Co. and the electrical motors and control equipment were supplied by the British Thomson-Houston Co. of Rugby, who also supplied the generating plant and switchboards, Figs. **8** and **9**. The system adopted to drive the machines is novel and involves the use of two separate electrical supplies throughout the ship, one the normal constant voltage supply of 220 volts used for lighting etc. and the other a constant current supply of 300 amperes and variable voltage used on the armatures of the cable engine motors and also on the anchor windlass and capstan motors. These motors are controlled by variable field excitation from the 220 volt supply.

The forward cable engines are fitted each with 160 h.p. motors. To obviate changes in the cable engine in adapting it to electric drive the motors were fitted by the makers with double helical reduction gears having a ratio of 940/240 r.p.m. The cable engines are arranged for two ratios of gearing giving at the drum surface a slow speed of 0·75 nautical miles per hour with a load of 26 tons or a fast speed of 3 nautical miles per hour with a load of 6½ tons.

The after cable engine is fitted with an 80 h.p. motor which can be used for braking purposes as an alternative to or supplementary to the fan and friction brakes. It is also used to drive the paying-out machine when commencing operations as, until sufficient cable has been paid out to provide a drag, the machine will not operate unaided.

The constant current is generated by

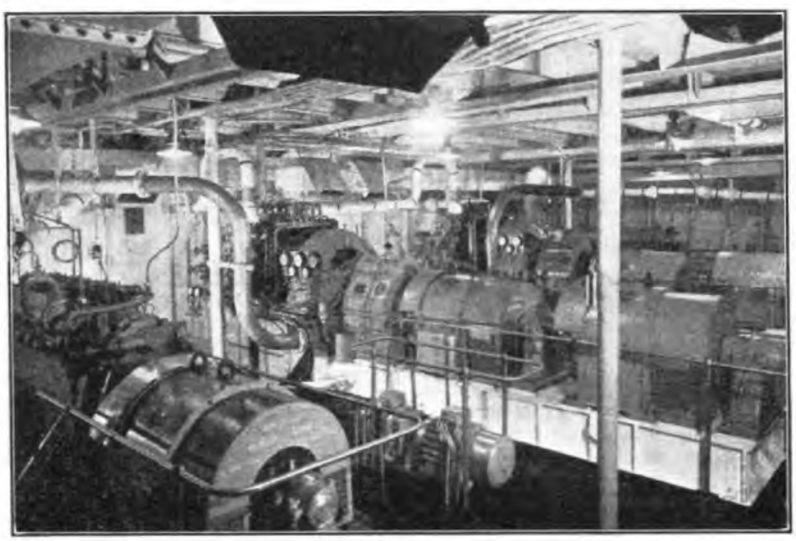


Fig. 8.—Turbo Generators, Oil Engine Sets and Amplidyne.

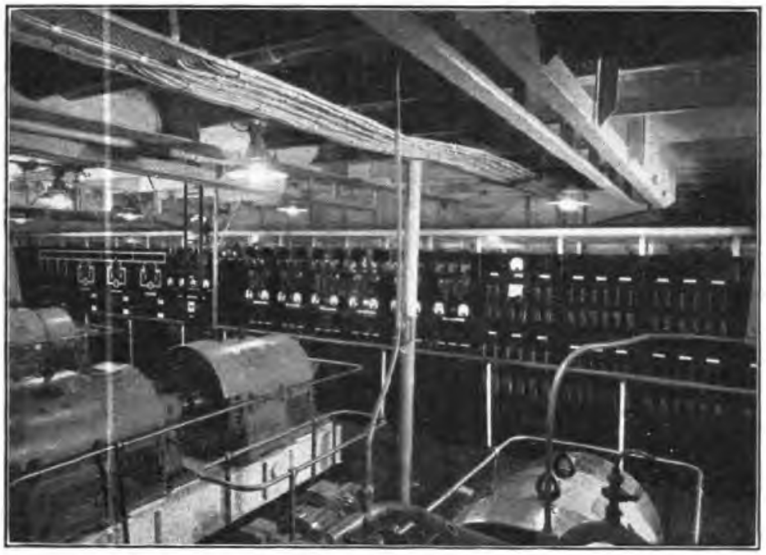


Fig. 9.—Switchboard; Constant Current Section to Left; Constant Voltage Section to Right.

for the motor to overcome the load the machine picks up speed and immediately the generator in the power room, which up to then has been developing only 10 to 15 volts sufficient to circulate the 300 amperes round the ship, responds and applies more voltage.

The system is one having great flexibility and the whole range of control is effected in a very economical manner, as the only control resistances employed are in the field circuits which carry comparatively low currents. Moreover, the system is completely and automatically regenerative. If a motor is under-excited so that it is driven by the load the voltage generated by the machine assists the main generator. In this way the power developed by a cable being paid out can be used to light the ship. Also the brakes on one cable engine can be used to supplement the braking on another cable engine by the electric coupling. Because these motors have steam-engine characteristics under load, they also have the steam engine's ability to run away under no load or light loads if uncontrolled. On each cable engine motor an over-speed trip is provided, actuated by a small D.C. generator fitted to one of the motor bearings. This generator also operates a tachometer mounted near the motor control pedestal. On the anchor windlass and capstan motors which, with their control gear, were supplied by Messrs. Laurence Scott & Co. Ltd., a small generator is mounted on an extension of the motor shaft which modifies the field so that at each position of the controller the motor has a defined speed limit. The motors may be disconnected from the series distribution circuit by bringing the field to zero and then operating contactor gear which short-circuits the armature and then isolates it. The cable engine motors may have to remain stopped for periods while full current of 300 amperes passes through the armature. They are provided, therefore, with a separate fan which starts up automatically when the cable engine motor is in circuit.

The ease of control provided by the electrical gear is very marked, particularly when changing from one tank to another. At such times it is necessary to slow up and even to stop the paying-out while clearing the bight of cable between the tanks. The instant response of the motor to the easily manipulated control gear makes this a simple matter.

Electrical Generating Plant.

The electrical generating plant consists of two steam turbines of the impulse type mounted on individual condensers. They revolve at 8,000 r.p.m. and drive through gearing two 100 kW generators in tandem at 1,200 r.p.m. One generator of each set is a dual purpose machine; the other is permanently connected to the constant voltage board. Both machines are compound wound and when the constant current is not required both machines share the constant voltage load.

The turbo-generator sets are completely self-contained, with their own condensers, air ejectors, circulating and condensate pumps. Thus they are independent of the main engine condensers and circulating and air pumps, etc. which can be shut down when the main engines are out of use.

In addition to the turbine sets there are two 100 kW generators driven by eight cylinder Paxman-Ricardo oil engines. One of these generators is a dual purpose machine for either constant current or constant voltage work, the other being for constant voltage work only. These sets provide for lighting and power under emergency conditions or when the ship is in port and the boilers are not under steam.

The main switchboard is in two sections. On the starboard side (left in Fig. 9) six panels control the constant current service. They consist of an excitation panel containing the amplidyne controls, three generator panels and two distribution panels. A mimic diagram along the top of the board discloses immediately the condition of the plant. For example, in Fig. 9 it will be seen that the second generator is connected to the constant current circuit and current is circulating to both forward and after distribution circuits. The handwheels on the generator panels operate change-over switches behind the board to transfer a machine from constant voltage to constant current and vice versa. The constant current circuit, which may go up to 700 volts, is excluded from the front of the board.

The constant voltage section of the switchboard (centre and right in Fig. 9) consists of six generator panels each fitted with 600 ampere circuit-breakers with overload and reverse current trips and distribution panels fused for varying loads from 300 amperes downwards. The main distribution feeders go to sub-distribution boards in various parts of the ship. In addition, certain important services such as the supply to the electro hydraulic steering gear, degaussing, etc., are supplied directly from the main board. A panel is also provided to enable a shore supply to be accepted from a connection box on the shelter deck.

The constant current mains as well as the constant voltage feeders are of Pyrotenax cable. In this type of cable the conductors are insulated with mineral dielectric and are sheathed in copper. The whole cable—conductors, insulation and sheath—is drawn down by a process similar to wire drawing from an initial assembly some inches in diameter. The cable is fireproof, almost immune from damage by rough usage, compact in layout, needs no protection and is ideal for ship work. It is used throughout except for local lighting distribution. Its neat appearance will be noticed in Fig. **8** in the wiring to the amplidyne terminal box and in Fig. **6** in the wiring to the main motor.

Miscellaneous Equipment.

Space does not permit, in the course of this short article, giving a complete description of the vessel or of the many problems which arose and required solution during its construction. For example, owing to the size of anchors and the need for placing the anchor windlass well forward on the main deck to leave the upper or shelter deck clear, it was impossible to " pocket " the bow anchors. Heavy steel guards have been fitted, therefore, to prevent the cable chafing over them. It was possible to pocket the stern anchor and this has been done. At the stern also is fitted a derrick to carry a marking buoy which can be dropped in emergency.

Additional hawse pipes have been provided on the bow to enable the anchor chains to be removed from the anchors and used for mooring purposes.

In many respects *Monarch* does not differ noticeably in her equipment from other large cable ships built in the past, such as *Dominia*, *Colonia*, *Faraday*, etc. Apart from the electrical drive the cablemachinery, including dynamometers, etc., is normal. Taut-wire gear is provided aft for paying out a steel wire to measure the actual distance travelled by the ship relative to the sea bottom. A pulley, rotated by the wire as it is paid out, is coupled to a drive from the after cable engine through an indicator gear so as to provide a visual indication of the percentage of slack in the cable as it leaves the ship. This indicating equipment is contained in the after drum room which is also equipped with remote indicators on the dynamometer, ship's speed repeater from the Pitometer, engine revolution telegraphs and cable engine brake and clutch controls.

As usual in a ship of this size, a well equipped electrical testing room is provided forward on the shelter deck, Fig. **10**. This is fitted with the usual assembly of high-grade bridges, resistances and galvanometers, etc., to enable the required measurements of conductor resistance, insulation resistance, capacitance, etc. to be carried out. The terminal board on the left of the picture is connected to the cable terminal boards above the tanks by double screened conductors. Provision is also made for high frequency A.C. testing which becomes necessary with telephone carrier cables.

Fig. **10**.—Cable Testing Room.

Trials.

On completion at the builder's works, speed, steering and manœuvring trials were carried out off the N.E. coast. The weather conditions at the time were not ideal, as there was a 20 to 25 knot wind blowing. Her performance demonstrated the exactness with which the model test simulated the full-sized performance, for example, at full speed the average of two runs in opposite directions was 14·49 knots at 111 r.p.m. and 4,935 i.h.p. with $2\frac{1}{2}$ in. of air pressure at the fan outlet and $\frac{1}{2}$ in. in the furnaces.

Following on the builder's trials she was taken over by Commander R. H. J. Wallis and proceeded to the Gareloch where a length of deep sea telegraph cable was taken on board. Trials of the cable-laying machinery were then carried out in the Atlantic about 300 miles S.W. of the Scilly Isles, where the depth changes rapidly from a few hundred fathoms to 1,500 to 2,000 fathoms. A length of cable being laid with the after gear is shown in Fig. **7**. Trials were made using the friction brakes, the air fan brake and the electric regenerative brake, and showed that these could be used alone and in combination and provided the fullest control of operations including changing over of cable tanks. The cable in deep water was then successfully grappled and recovered using the forward starboard cable engine. To do this in very deep water it is usually necessary to relieve the strain on the cable by using the Lucas cutting and holding grapnel. This device, which is shown in the open position in Fig. **11**, is arranged so that no matter in what position it lies it cuts the cable and holds one of the ends; which is predetermined by the setting of the grapnel. The inset shows the grapnel in the closed position with one end of cable retained after having cut the loop of cable at a depth of about 1,700 fathoms. Actually, this depth of water did not make its use essential, but it was desired to test its working. The sea conditions during these operations were, at times, far from calm.

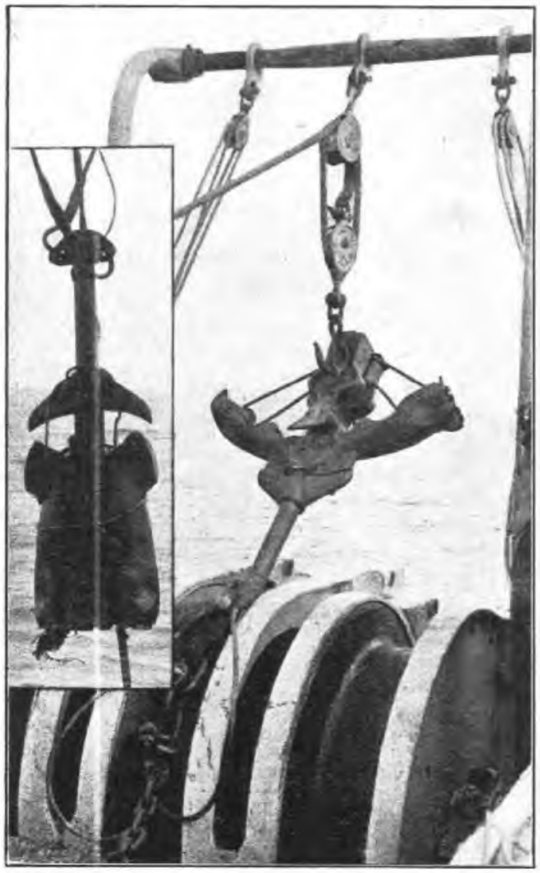


Fig. 11.—Lucas Grapnel in Open Position (Inset Closed).

but the ship exhibited excellent sea qualities—contributed no doubt in a great measure by the 24 in. bilge keels with which she is fitted.

The performance of the cable engines under electric drive was entirely satisfactory under the heaviest loads, with an improvement in quickness of handling and control as compared with steam driven gear. In this connection it should be pointed out that these advantages obtain when the cable engine supply is derived from the 100 kW oil engine driven generator.

Conclusion.

The choice of the name *Monarch* was a natural one. The first cable ship of this name was a small wooden paddle steamer and the first vessel permanently fitted as a cable ship. She laid some of the earliest continental cables and when the Post Office took over the submarine cable system in 1870 she was scrapped. A new replacing vessel of the same name was built for the Post Office by Messrs J. & D. Dunlop in 1883; this was the first ship to be built specially as a cable ship, all previous ones having been conversions. She was sunk by enemy action in 1915 and replaced in 1916 by another *Monarch* built by Messrs. Swan, Hunter & Wigham Richardson, which was sunk in turn in 1945 just when it became necessary to choose a name for the present ship. May she be luckier than her two predecessors in this respect.

In conclusion the writer would like to pay tribute to the wonderful co-operation at all times between the builders and the Post Office and also to mention the valuable contributions made to her design and layout by Capt. Firmin, late Submarine Superintendent, and by Mr. J. Sloss, her present Chief Engineer.

TELEGRAPH AND TELEPHONE STATISTICS—SINGLE WIRE MILEAGES AS AT SEPTEMBER, 1946, THE PROPERTY OF AND MAINTAINED BY THE POST OFFICE

REGION	OVERHEAD			UNDERGROUND		
	Trunks and Telegraphs	Junctions	Subscribers*	Trunks and Telegraphs †	Junctions ‡	Subscribers ¶
Home Counties	12,538	41,802	354,672	1,873,015	427,986	1,454,380
South Western	6,382	39,100	268,253	963,471	178,279	805,080
Midland	4,722	35,106	212,780	1,025,878	302,082	1,053,642
Welsh and Border Counties	7,444	30,794	149,925	533,712	82,876	333,807
North Eastern	9,815	21,411	179,316	852,126	249,699	1,019,717
North Western	1,822	9,255	111,372	654,521	394,640	1,269,785
Northern Ireland	9,816	11,453	35,177	109,886	43,544	144,725
Scottish	20,632	34,705	186,803	766,250	248,205	865,463
Provinces	73,221	223,626	1,498,298	6,778,859	1,927,311	6,946,599
London	467	1,545	76,956	916,377	1,793,038	3,792,628
United Kingdom	73,688	225,171	1,575,254	7,695,236	3,720,349	10,739,227

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

The Heat Pump

E. E. CHARLES, A.M.I.E.E.

U.D.C. 697.3 : 621.52

It has been known for nearly a century that a refrigerator could be used in reverse as a heat pump for space or water heating. Recently increases in fuel and labour costs have caused increasing attention to be given to this method of heating. The author describes the principle of the heat pump and a typical installation.

Introduction.

IT was in 1852 that Lord Kelvin first pointed out that a refrigerator worked on the reversed cycle would serve as a heat pump. This suggestion was not followed up practically at the time, possibly because the existing plentiful supply of low cost fuel and labour did not justify the adoption of plant of this nature, but the rising cost of fuel and labour difficulties have caused increasing interest to be taken in the possibilities of space heating by the heat pump. Within recent years a number of heat pump systems has been installed mainly in America and Switzerland, but the only extensive trial in this country is that now being made by the City of Norwich Electrical Engineer, test results of which are not yet available.

The refrigerator, as is well known, extracts heat from the body to be cooled and gives this extracted heat up either to the cooling system, or to the surrounding atmosphere. The heat pump, on the other hand, extracts heat from the atmosphere or other warm body and gives up this heat to the cool body, or space to be heated.

Description of Elementary Plant.

Fig. 1 shows a simplified schematic diagram of a

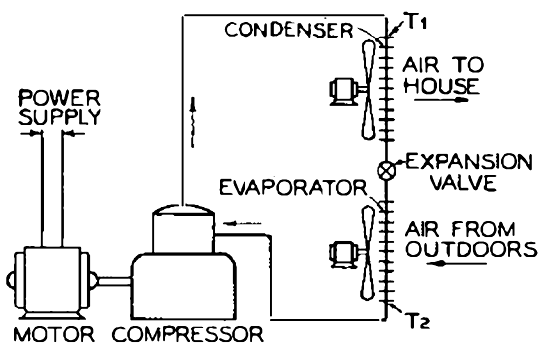


FIG. 1.—SIMPLIFIED SCHEMATIC DIAGRAM OF DIRECT EXPANSION HEAT PUMP.

direct expansion heat pump where the atmosphere is used as the primary source of heat and in which the refrigerant is a substance possessing the following main qualities ; low boiling and condensing temperature, high latent heat to reduce the quantity circulated to a minimum, non-inflammable, and non-explosive even when mixed with air ; it must also be non-toxic and free from obnoxious odour.

A refrigerant now much used is Freon 12, which has a boiling point of $-21{\cdot}5°F$ and a latent heat of evaporation of 69·5 B.Th.U. per lb. and has the other desirable qualities mentioned above.

Air from outside the building is drawn by the auxiliary evaporator fan over the surface of the evaporator coils, where it gives up some of its heat to the refrigerant, and is then returned at a lower temperature to the general body of the atmosphere. Prior to this, the refrigerant had passed through the regulating expansion valve, where its pressure had fallen to that of the compressor inlet with a corresponding reduction in temperature. The heat extracted from the atmosphere is absorbed in supplying latent heat required to produce a change of state in the refrigerant and then in raising its temperature ; a further increase in its pressure and temperature is produced in its passage through the compressor, which is assumed to be electrically driven. Some of the heat thus gained from the two sources (viz., the outside air and the compressor) is given up to the air required for space heating which is drawn by the second auxiliary fan over the condenser coils through which the refrigerant next flows. The temperature of the refrigerant falls rapidly in the condenser where the refrigerant vapour condenses. It then passes through the expansion valve where the further fall of temperature mentioned earlier, takes place.

Theoretical Efficiency.

In general the efficiency of a piece of apparatus is given by the ratio between the output and input and has a value less than unity. If the heat pump is considered on this basis, it will be found that this ratio may be considerably greater than unity. With a simple heat pump, ignoring auxiliaries such as the two air fans shown in Fig. 1, the only direct input is the power required to drive the compressor, while the heat output, i.e., the heat added to the space to be heated, is the sum of the heat extracted from the primary source (the atmosphere in Fig. 1), and that resulting from compression of the refrigerant ; this sum may be many times the equivalent of the direct input and from this fact the misleading idea of efficiencies greater than unity results. For this reason the ratio is called by some writers the "Coefficient of Performance" ; Dr. Faber in his recent paper referred to it as the "Coefficient of Advantage."

The theoretical maximum value of the coefficient of performance can be deduced from Carnot's law and is the ratio of the heat given out at the higher temperature to the energy absorbed in operating the pump and system. The Carnot cycle is shown in Fig. 2.

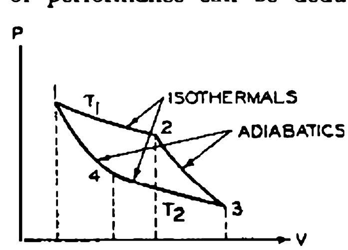


FIG. 2.—THE CARNOT CYCLE.

This cycle is an ideal and theoretical cycle consisting of four reversible operations, two of them being adiabatic and two isothermal. An isothermal expansion is one in which the temperature of the expanding substance remains the same, or more strictly, an isothermal expansion is defined as an ideal and reversible expansion which takes place at constant temperature. An adiabatic expansion is one in which heat is allowed neither to enter nor leave the substance during expansion, or more strictly, an adiabatic expansion may be defined as an ideal and reversible expansion in which no heat is allowed to enter or leave the substance.

The transference of heat and work done during the four operations of the Carnot cycle are shown in Table 1.

TABLE 1.

Process	Heat supplied to working fluid by hot source at T_1	Heat rejected from fluid to receiver at T_2	Work done by working fluid	Increase in internal energy of working fluid
Isothermal expansion 1—2	$Rm\,T_1 \log_e r$	0	$Rm\,T_1 \log_e r$	0
Adiabatic expansion 2—3	0	0	$\frac{Rm\,(T_1-T_2)}{\gamma-1}$	$-\frac{Rm\,(T_1-T_2)}{\gamma-1}$
Isothermal compression 3—4	0	$Rm\,T_2 \log_e r$	$-Rm\,T_2 \log_e r$	0
Adiabatic compression 4—1	0	0	$-\frac{Rm\,(T_1-T_2)}{\gamma-1}$	$\frac{Rm\,(T_1-T_2)}{\gamma-1}$
Totals ..	$Rm\,T_1 \log_e r$	$Rm\,T_2 \log_e r$	$Rm\,(T-T_2) \log_e r$	0

Where R is the gas constant,
m is mass of one pound of gas,
γ ratio of specific heats,
T_1 and T_2 absolute temperatures,
r is ratio of adiabatic or isothermal expansion,
i.e., $\frac{V_2}{V_1}$; $\frac{V_3}{V_4}$ (Fig. 2).

From this table it is seen that in the Carnot cycle the total work done by the fluid is $Rm\,(T_1-T_2)\log_e r$ from a supply of heat $Rm\,T_1 \log_e r$.

Hence the efficiency of the Carnot cycle is :—

$$\eta = \frac{\text{work done}}{\text{heat supplied}} = \frac{T_1-T_2}{T_1}$$

The heat pump works on the reversed Carnot cycle, the external work, $Rm\,(T_1-T_2)\log_e r$, being supplied to do work on the fluid in order to pump an amount of heat $Rm\,T_1 \log_e r$.

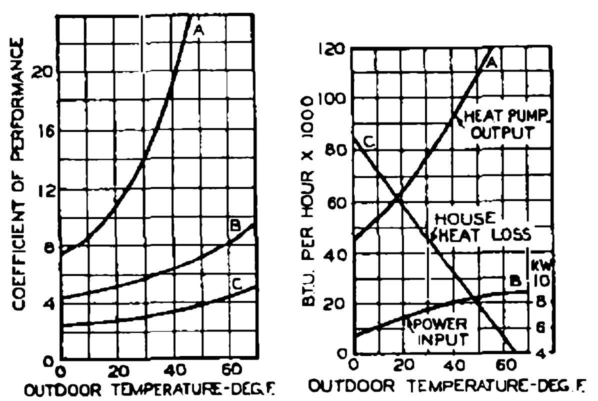
The coefficient of performance therefore is given by :—

$$\text{C.P.} = \frac{\text{heat supplied}}{\text{work done}} = \frac{T_1}{T_1-T_2}$$

Another view of the coefficient of performance is that it indicates the ratio of the heat made available for heating purposes by the heat pump to the heat equivalent of the power used in driving the pump. It will be evident from consideration of the coefficient of performance ratio that the more nearly the temperature of the source of heat approaches that required for space heating, the higher the coefficient and conversely the greater the temperature difference the lower the coefficient. For this reason, atmospheric air, although it can be used as a source of heat, even when its temperature is below 32°F if suitable arrangements for defrosting the evaporator coils are made, is far from ideal, and a warmer source is preferable. Such a source can be found in well or river water, in waste process heat or in engine cooling water. Another point is that at low values of coefficient of performance, the input power to the compressor also falls because of the decrease in the circulation of the refrigerant at low suction densities as the evaporator temperature and pressure falls. This compensating feature is, however, of insufficient magnitude materially to alter the economics of the system.

Description of Installation.

As stated earlier, there is very little first hand practical experience of the heat pump available in this country, but it is understood that in America a number of private houses and office buildings have systems working as refrigerators during the summer and as heating systems during the winter. Fig. 3



(a) (b)

FIG. 3.—(a) EFFICIENCY CHARACTERISTIC OF A HEAT PUMP MAINTAINING HOUSE TEMPERATURE 70°F.

CURVE A—THEORETICAL C.P. CURVE B—C.P. AFTER ALLOWING FOR REFRIGERANT. CURVE C—ACTUAL C.P.

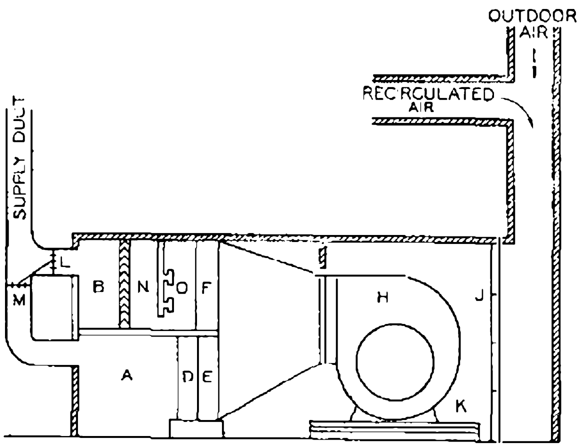
(b) OUTPUT CHARACTERISTICS OF HEAT PUMP HAVING CONSTANT SPEED 7½ H.P. COMPRESSOR.

(a) and (b) shows typical curves for such an installation as a heating system, assuming heating requirements of 85,000 B.Th.U./hr., a 7½ H.P. compressor motor being used and the evaporator unit using outdoor air.

The capital cost of such an installation is understood to be about £550, that of a standard hot water heating coke fired boiler system would be about £175 for the same B.Th.U. output. It will be appreciated that in a country like ours, where until recent years coal supplies have been plentiful and cheap, the incentive to seek an alternative to coal or coke as the normal heating fuel has been slight, but in a country like Switzerland where these conditions do not apply, the urge has been greater. The climatic conditions in many parts of America are such as to make summer air cooling necessary, and particulars of several heat pump installations working as refrigerators during the summer have been published.

One such installation is that at the Ohio Company's office building at Coshocton, Ohio, and it has been described by P. Sporn and E. R. Ambrose[1].

This building stands on a reinforced concrete foundation, and consists of two storeys and a basement, having a total capacity of approximately 150,000 cu. ft. The exterior walls are made up of clay blocks faced with brick and are 1 ft. thick. All windows are fixed and have double glazing. The floors are constructed of reinforced concrete on



A—Cold air plenum.
B—Warm air plenum.
D—Cooling coil.
E—Pre-cooling coil.
F—Heating coil.
H—Fan.
J—Filters.
K—Fan motor.
L—Damper.
M—Damper.
N—Eliminator plates
O—Humidifying sprays.

FIG. 4.—CONDITIONING UNIT AT COSHOCTON.

open web joists and the space between the floor and ceiling is utilised as an air return for the conditioning system, which is housed in the basement, distribution of the air being carried out by galvanised iron ducts.

This installation differs from the one previously mentioned in that well water at a temperature of 55°F is available and is used as the heat source during the winter months, and also serves as the sink into which heat is rejected during the summer months.

The design and capacity of the plant is based on a minimum outdoor temperature, occurring during the heating season of 50°F and a summer maximum temperature of 95°F, the indoor room temperature to be maintained at 72°, 30 per cent. relative humidity during the winter and 78°, 50 per cent. relative humidity during the summer. These data fixed the heat loss at 409,700 B.Th.U./hr. and the heatgain 404,700 B.Th.U./hr. The demand on the plant during winter and summer being approximately equal enables the refrigerant compressors to operate at approximately the same suction pressure during both the heating and cooling cycle.

The general arrangement of the conditioning unit is shown in Fig. 4.

This unit consists of an electrically driven fan encased in a housing, together with the auxiliary units necessary for filtering, cooling, heating and humidifying the air. The fan circulates 11,000 cu. ft. of air per minute of which 8,500 cu. ft./minute is recirculated air, and 2,500 cu. ft./minute is air from outdoors. The whole of the intake first passes through the filter bank J and then according to the setting of the dampers, passes either over the heater coil F, the humidifying sprays O, and then to the warm air plenum, via the eliminator plates N, or into the cold air plenum A via the pre-cooling coil E and the cooling coil D. By suitably arranging the dampers, portions of the flow can be directed to A and B chambers as desired. The dampers L and M are thermostatically controlled and the required amount of air flowing from each of the chambers to the main supply duct is thereby ensured. The heater coil F, the pre-cool coil E, and the cooling coil D are in the refrigerant circuit, water being used to transfer the heat from the conditioning unit to the heat pump.

Fig. 5 shows the water circuit for the combined heat pump and air conditioning system.

All the water reversing valves, shut-off valves, and thermostats are pneumatically operated and interlocked with the various electric starting switches controlling the motors, the operation of which will be dealt with later. During the heating cycle water from the deep well, which is the source of heat, is circulated by the pump A via the valve V4, position 1-2 to the evaporators 1 and 2. After passing through the evaporator the main distribution is then via the cooling coil D (see Figs. 4 and 5), valves V3 and V7, position 1-2 to the discharge

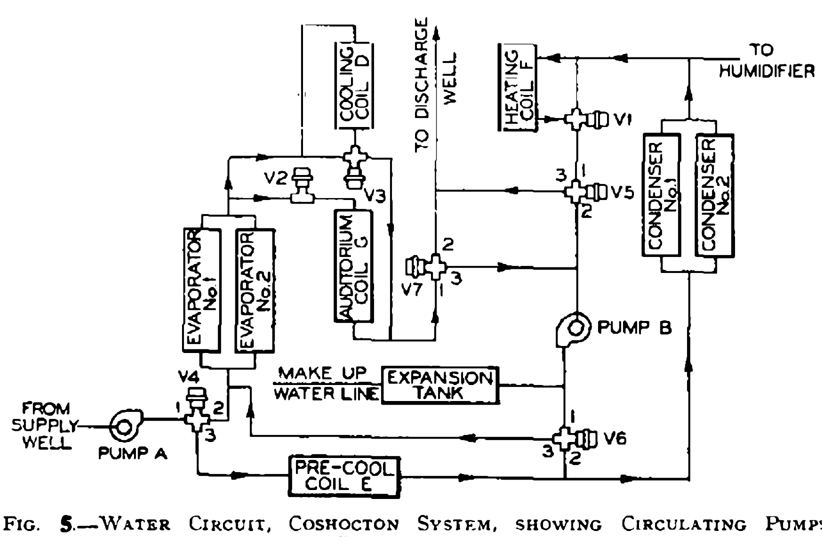


FIG. 5.—WATER CIRCUIT, COSHOCTON SYSTEM, SHOWING CIRCULATING PUMPS AND REVERSING VALVES.

	Heating Cycle	Cooling Cycle		Heating Cycle	Cooling Cycle
Valve V4	Position 1—2	Position 1—3	Valve V6	Position 1—2	Position 1—3
Valve V5	Position 1—2	Position 1—3	Valve V7	Position 1—2	Position 1—3

[1] "Description and Performance of Two Heat Pump Air Conditioning Systems"; *Heating, Piping and Air Conditioning*, June, 1944.

well; the subsidiary portion being taken via V2 to an additional cooling coil G to serve the auditorium, where special conditions are required. This flow is then similarly rejected to the discharge well via V7 position 1-2. Pump B circulates water through the circuit formed by V6 position 1-2, condensers 1 and 2, heating coil F, valves V1 and V5 position 1-2. Cooling is carried out by setting valve V4 to position 1-3, the circulation being via the pre-cool coil E to the condensers 1 and 2, heating coil F, valves V1 and V5 position 1-3 to the discharge well. Under this condition pump B circulates water through the loop formed by V6 position 1-3, water coolers 1 and 2 coils D and G, valves V3 and V7 position 1-3 back to the pump.

It will be seen that the pumps A and B serve purposes similar to the evaporator and condenser fans in the simple air system shown earlier in Fig. 1, i.e., they cause the medium containing heat, in this case water, to circulate over the evaporator, and

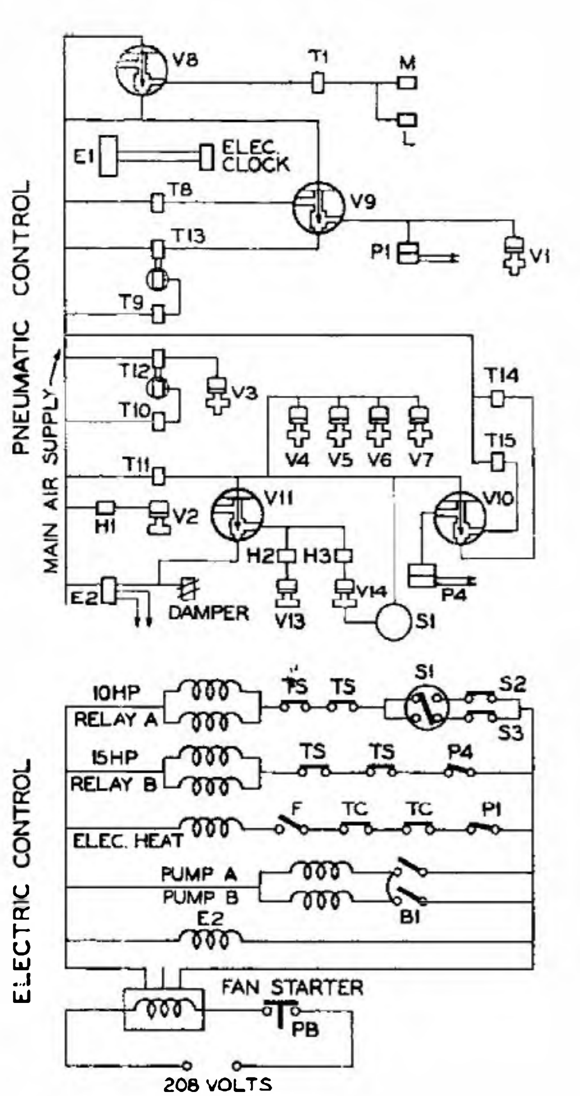


FIG. 6.—ELECTRIC AND PNEUMATIC CONTROL DIAGRAMS FOR COSHOCTON INSTALLATION.

the medium to be heated to circulate over the condenser.

The changeover from the heating cycle to the cooling cycle is effected automatically by an outdoor thermometer set to operate a thermostat whenever the temperature drops below or rises above predetermined settings. Fig. 6 shows the electric and pneumatic control diagrams for the operation of the system.

When the fan push button is closed, starting the fans, the operation of the system is entirely automatic, the room temperatures being maintained by thermostats T1, which set the automatic dampers (Fig. 4) in the air supply duct to the required position. To operate the plant economically, the temperature at night is lowered during the heating cycle, the electric clock switching the control from the room thermostats T1 to the return duct thermostat T8.

Operation of the outdoor thermostat T11 by a fall in temperature causes valves V4, V5, V6, V7 and all controls to change over to their heating positions. The relay controlling the 10 H.P. motor driving one compressor unit is energised via the pressure switch S2, the double throw switch S1, and the electrical immersion thermostats TS on the inlet and outlet of both coolers. The relay controlling the 15 H.P. motor driving the other compressor unit is energised by operation of the pressurestat P4, through the immersion thermostat T14 located in the condenser discharge. The temperature of the plenum B is controlled by thermostat T13 controlling the valve V1, on a falling temperature. V1 is readjusted by thermostat T9 to a higher setting. The pneumatic safety control thermostat T15 and the electrical immersion thermostats T3 stop the compressor should the water temperature fall below their setting; when the compressor cannot maintain the required temperature in plenum B the pneumatic electric switch P1 switches in a 15 kW auxiliary heater. Operation of the outdoor thermostat T11 by a rise in temperature changes the valves V4, V5, V6, V7 and all controls to their cooling position. The 10 H.P. compressor motor is controlled by the switch S1 switching to the suction pressure switch S3. Water valve V3 readjusted to lower settings as the outdoor temperature rises by the thermostat T12 in the return air, thus controlling the temperature in plenum A. Humidity is controlled by valve V2, which is opened by the humidistat H1 on a rise in humidity.

Table 2 show the results of test data obtained on the system.

The test data shown in Table 2 is not representative of all operating conditions, but indicates the performance of the equipment under three different operating conditions when the outside temperature is roughly the same. Under conditions where the heat requirements of the building balance the maximum output of the system, slightly higher coefficients of performance of the order of 3·6 average would have been obtained. The fall in the C.P. figure at the higher output is due to the 15 H.P. compressor condensers being the same size as the 10 H.P. condensers, thereby causing the 15 H.P.

TABLE 2.

ACTUAL PERFORMANCE DATA.

	TESTS		
	No. 1	No. 2	No. 3
Supply air to conditioned space, cubic feet per minute	11,000	11,000	11,000
Temperature, degrees Fahrenheit	78·6	80·5	94·3
Outside air, cubic feet per minute	2,500	2,500	2,500
Temperature, degrees Fahrenheit	37	35	35
Conditioner Heating Coil (Coil F, Fig. 5)	88	92·8	113·5
Entering Water Temperature, degrees Fahrenheit	83	87	103
Gallons per minute	70	70	70
Water Cooler (Fig. 5)—			
Entering Water Temperature, degrees Fahrenheit	55	55	55
Leaving Water Temperature, degrees Fa renheit	47	46·5	47·3
Gallons per minute	37	38	75
Electric Consumption—			
Compressors, Kilowatts	10·2	15·5	27·5
Auxiliaries, Kilowatts	5·2	5·2	5·2
Total Kilowatts (*a*)	15·4	20·7	32·7
Capacity—			
Refrigeration, B.Th.U./hr.	148,000	161,600	288,600
Heat Output, B.Th.U./hr.	175,000	203,800	366,600
Coefficient of Performance—			
Using Kilowatt input to Compressors	5	3·85	3·9
Using Total Kilowatt input (*b*) ..	3·5	3·0	3·3

Test No.—

1—10 H.P. Compressor, 120 lbs/in.² head pressure—40½ lbs/in². Suction

2—15 H.P. Compressor, 140 lbs/in.² head pressure—35 lbs/in.² Suction

3 { 10 H.P. Compressor, 160 lbs/in.² head pressure—42½ lbs/in.² Suction
  { 15 H.P. Compressor, 176 lbs/in.² head pressure—38½ lbs/in.² Suction

Note : (*a*) kW to conditioner supply fan not included.
(*b*) 60 per cent. of auxiliaries kW input considered useful heat.

compressors to operate at a slightly higher head pressure, causing an increase in its power input, and hence a reduction in the C.P.

The auxiliary equipment causes the C.P. to be reduced by from 15 to 30 per cent.

Fig. 7 shows a comparison of the output cost in B.Th.U. per penny of a coke fired hot water heating system, and a heat pump installation at varying cost of fuel (coke and electricity) charges. A C.P. of 4 and an efficiency of 70 per cent. have been chosen as favourably representative of the present day performance of both systems. Curves C and D show the curves when allowance for the annual charges due to capital costs have been added to the fuel costs.

Conclusion.

The Norwich experiment will give valuable data on which it may be possible to estimate the future possibilities of the heat pump as a standard method of heating buildings, but at the present time the writer's opinion is that a coke fired hot water system will be more economical considered solely as a heating system. The heat pump may justify itself in climates in which, as in many parts of America, summer time air conditioning, including refrigeration, is standard, as the initial cost of the installation, which is comparatively heavy, will be spread over the whole year's use. The direct use of high grade electrical energy for heating is wasteful in that approximately 4 tons of coal are used in providing electric power of heating value equivalent to one ton of coal. Where it is the intention to carry out space heating electrically by directly dissipating the energy in resistances the use of the heat pump can effect economy both in the cost and in the conservation of the network and supply capacity for operations where the use of high grade electrical energy is essential. The heat pump would deserve serious consideration also where considerable amounts of waste high grade heat are available and where its supply is steady. Apart from economic grounds, however, the position as regards both the getting of coal and the need for conservation may make it necessary to reconsider the subject from that angle in years to come.

The author desires to acknowledge advice given in the preparation of this article by Mr. H. R. Marr, of the Engineer-in-Chief's Office, Power Branch.

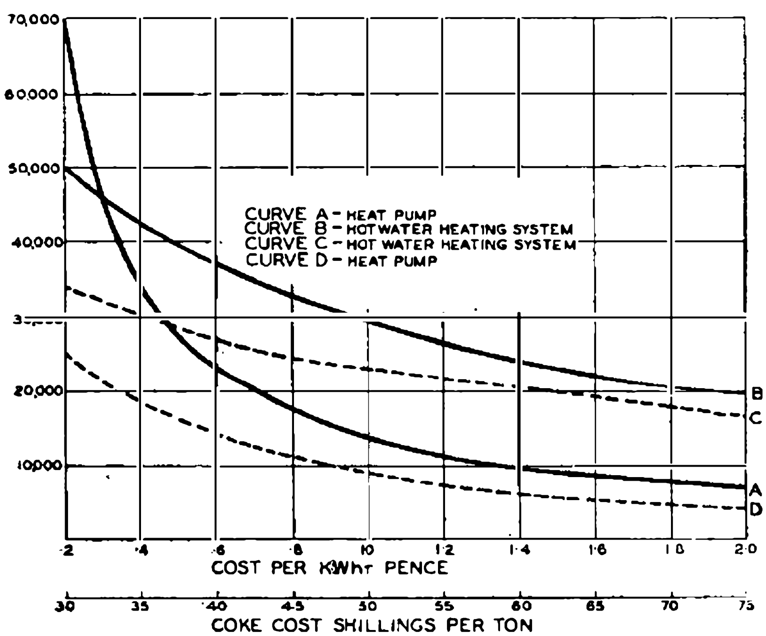


FIG. 7.—CURVES SHOWING RELATIVE COST OF HEAT UNITS BASED ON BOILER EFFICIENCY 70% AND HEAT PUMP COEFFICIENT OF PERFORMANCE OF 4.

A Lightweight Moledrainer

D. B. AFFLECK, A.M.I.E.E.

U.D.C. 621.315.233

The author describes a lightweight type of moledrainer used for laying subscribers' cables up to 7pr/20 lb. The moledrainer can be towed by a 2-ton Albion or a small tractor.

Introduction.

THE Peterborough Area, which is mainly rural in character, has been faced with the problem of providing telephone service to a large number of farmers. As a general rule their houses are remote from any existing overhead routes and provision of service by normal methods of construction would entail the erection of numerous poles. In two cases as many as 90 poles for each applicant would have been wanted. A selection of 171 cases on the waiting list would have required 3,675 poles. The employment of the small amount of labour available on works of such magnitude would seriously impede progress on other works, and with the shortage of poles growing more acute a search had to be made for some means of providing service which would show an appreciable saving in labour and poles.

A solution has been found in the use of a light moledrainer which will lay small sizes of cable direct in the ground. It has been used along grass verges of public roads as well as along the margins of private roads leading to farms. The soft fen soil which preponderates in the most intensely farmed parts of the Area seemed admirably suited to this method of construction, and results achieved have amply justified expectations.

Description of the Moledrainer.

A moledrainer adapted for cable laying direct in the ground has been described in this Journal[1], but that implement was fitted with a 2½-in. mole and required a 45-60 H.P. tractor to pull it. A much lighter device which could be pulled by one of the Post Office vehicles or by a small tractor has been found. The machine is a Howard's " Wholroot R " Beet Lifter, manufactured by Messrs. Ransomes, Sims & Jefferies, Ltd., Ipswich, bought locally for £7 10s. (The price has since been increased to £8 8s.) By removing the beet lifting attachment from the bottom of the coulter and fitting in its place a piece of hardened steel shafting 1¼ in. in diameter and 19 in. long, cut at an angle of about 30° at the front, the machine was converted into a moledrainer with an exceptionally small diameter mole. For feeding the cable behind the mole a piece of ⅜ in. diameter W.I. pipe was welded to the back of the coulter, the bottom of this pipe being bent to a radius of about 6 in. and terminated just above the centre of the back of the mole. A conical shaped cup to hold petroleum jelly for lubricating the cable as it passes through the pipe and to provide some protection against corrosion was welded to the top of the pipe. In addition to the foregoing modifications some strengthening of the machine was found to be desirable and the whole of the strengthening and modification was carried out by the vendors for the sum of £3 15s.

[1] *P.O.E.E.J.*, Vol. 35, p. 41.

The depth at which the mole moves through the ground is adjustable to a maximum of 14 in. by altering the height of two wheels at the front. These wheels are independently adjustable, permitting the use of the machine on a sloping grass verge. The distance between them can also be varied.

Method of Operation.

The moledrainer can be pulled by any of the vehicles which can be used for drawing in cable, but the heavier vehicles with their lower gearing are more suitable. The 2-ton S.C. Albion has been found convenient and has been used also to transport the machine. The best results, however, are achieved with a small tractor of about 25 H.P., and most farmers for whom service was being provided have been very willing to provide a tractor to pull the moledrainer. This saves the transport of officially owned tractors. A length of 7/14 steel suspension strand has been used for towing, and between this and the machine, when using the Albion, is inserted a tension fuse consisting of two pieces of 400 lb. G.I. wire in parallel made off with clamps and thimbles. This breaks with a pull exceeding about 2,400 lb., and has been effective in protecting the machine and the vehicle against damage from obstructions such as tree roots and large stones.

Experience shows that there are few situations in which the machine cannot be used to lay cable at a depth of from 6 to 14 in. as an alternative to erecting an overhead route. It can be operated along any road where there is a grass verge more than about 18 in. wide even if it slopes at an angle not exceeding about 45°. In sloping ground the machine is kept vertical by the independent adjustment of the front wheels. Large stones up to about 6 in. in length are usually deflected without breaking the fuse in all but the heaviest soil and the coulter will generally cut through tree and hedge roots which are not larger than about 1 in. in diameter. The greatest difficulty is experienced in operating within a few feet from tree trunks as large roots near the surface frequently cause the fuse to break. When working in long grass a disc-coulter is attached to the machine as shown in Fig. 1. This assists in preventing the accumulation of grass in front of the knife coulter, which impedes progress.

The machine can successfully be operated by a party of five men who are employed as follows :— The first drives the towing vehicle, the second walks or rides with him keeping a watch on the moledrainer party for start and stop signals, the third takes the two handles of the moledrainer, the fourth feeds the cable into the conical cup, and the fifth walks alongside with a spade ready to cut away any grass which collects round the front edge of the coulter. Before operations begin, the cable is run off the drum and laid out alongside the track which is to be followed. Alternatively, if a tractor is available, the cable can

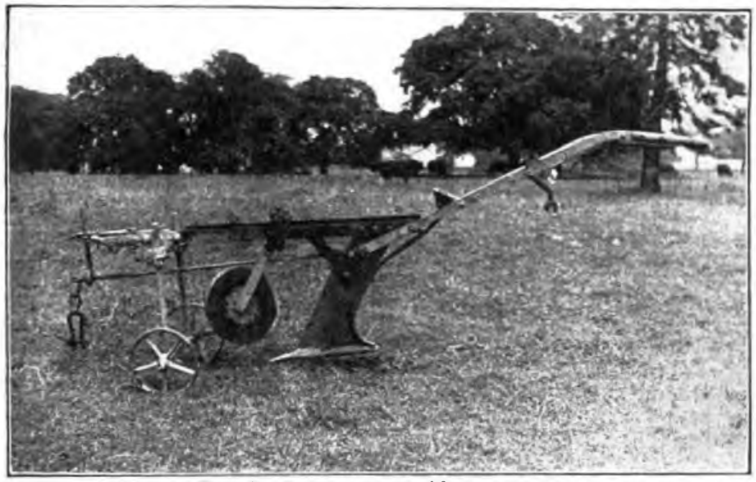


Fig. 1.—Lightweight Moledrainer.

be paid out from a drum mounted in a vehicle which travels alongside the moledrainer.

At unmade road crossings and field entrances it has been the practice to lay the cable, surrounded by a few inches of soft earth in a trench about 18 in. deep, and farmers, for whom the services have been provided, have been willing to excavate these trenches. It has, of course, been necessary to erect poles on either side of a road, or to lead in to the subscribers' premises, if continuing the underground cable would have involved an expensive reinstatement. It has also been necessary to excavate and lay the cable under drainage channels cut across grass verges.

A comparison between the costs of 44 Advice Note works completed up to May 1946 and the costs estimated to have been incurred had normal methods of construction been used is given in the following table :—

	Poles	Labour		Stores	Transport
		Manhours	£	£	£
Normal Construction	737	6,609	660	1,076	77
Moledraining..	77	3,420	342	907	20

Conclusions.

It remains to be seen whether this method of construction will create any maintenance difficulties. Experience gained with larger cables laid by this method round the perimeters of aerodromes during the war indicates that there is no reason to expect any difficulties. Faults on aerodrome cables have nearly all been due to one of two causes: damage by other contractors unaware of the existence of the cables and puncturing of the sheath by rodents. Damage from the first cause should be infrequent along public roads. It is believed that the large diameter mole had something to do with the attacks by rodents and that this trouble will be eliminated, or much reduced, by the use of the small mole. There is no case recorded so far of a mole-drained perimeter cable suffering breakdown from corrosion, and there is no reason to expect more serious corrosion of cables laid bare along public roads. However, the method has been in use too short a time to come to any conclusions regarding the corrosion aspect. Experiments carried out with a search-coil have shown that a mole-drained cable is very easily located.

The conclusion drawn from the experience gained with the light moledrainer is that it is a satisfactory method of providing telephone service where normal methods of construction would require an abnormally large number of poles. It has not been found necessary to confine the operations to one gang as the technique can be quickly learned by gangs stationed in different parts of the area. The method might very well come to be regarded as normal when providing service to isolated subscribers along roads which promise little or no development. Where only one pair is required the cable used is Cable I.R.V. Core T., 1 pr/12½ or, if its resistance would be too great, 1 pr/40. In some cases a cable containing more than one pair has been justified in a section of the route which is to serve two or more subscribers or where provision is being made to meet development. Multi-pair cables up to 7 pr/20 have been successfully laid with this machine.

Some Features of Deep Level Tunnelling in London

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U.D.C. 624.19 : 621.315.233

Part. I.—Driving Bore Tubes and Tunnels

The first part of this article deals with the civil engineering work involved in the construction of deep level tunnels, a number of which were provided in London by the Post Office during the war to safeguard its equipment and cables. The second part will describe the equipping of the tunnels with the necessary services for this purpose.

Introduction.

IN a recent article on "Safeguarding Telecommunications in Wartime"[1] reference was made to a system of deep level tunnels constructed during the war in the centre of London, with the object of providing the greatest practicable measure of protection to equipment and cables carrying vital telecommunication circuits. The rapid progress to completion which was achieved in the construction and equipment of these tunnels enabled the requirements of the Fighting Services to be met, and in the smaller tunnels, up to 8 ft. in diameter designed specifically for the accommodation of cables, it was possible to divert from congested surface routes many important trunk, toll and junction cables well in advance of the cessation of intensive enemy action in the London area.

In Part 1 it is intended to deal primarily with the civil engineering work involved in the construction of the tunnel system ; Part 2 will include a description of the various services with which the tunnels were equipped for telecommunications requirements and for the welfare of the staff employed in them.

General.

Before proceeding to describe the tunnelling operations, it is proposed to give a brief account of the history and character of the London clay through which the tunnels were driven, and of the operations involved in sinking bore tubes, a number of which provide cable routes from the Service Departments to the tunnel laterals. Although not related to the tunnel system, it is thought it may be of interest to refer also to the artesian well in the Faraday Citadel installed by the Ministry of Works.

The London clay provides a stratum well suited for tunnelling operations ; it is an impervious bed, roughly 100 ft. in thickness outcropping along a triangular boundary roughly formed by joining Great Yarmouth, Hungerford and Thanet. The area comprised within this boundary is known as the London Basin, but although the general shape of the clay stratum is in the form implied by the description, it is by no means smoothly graduated, and the high points give rise to the clay as subsoil in various localities ; moreover, in tunnelling operations at deep level in the London clay, there is always the risk of encountering the older Woolwich and Reading water-bearing gravel stratum.

Clay is a sedimentary rock and the London Basin was deposited when the area was submerged by a large estuary and under tropical conditions ; this is evident from the character of the plant and marine fossils found in the clay, the latter being similar to the molluscs now living in the Indian Ocean.

The bluish grey colour of the clay is due to finely disseminated sulphide of iron, but when found at or near ground level oxidation has resulted in the clay being stained brown by ferric hydrate. The SO_3 which was set free, however, by this chemical change combined with the calcareous matter of such fossils as were present to form selenite ($CaSO_4$, $2H_2O$). It is well known that these crystals which are often found in brown clay in certain areas of London have a deleterious effect on Portland cement[2], and it is the general practice in areas which are so suspect to employ aluminous cement for the construction of manholes or octagonal duct routes.

The valleys in the London clay surface constitute a bed for the various rivers or streams which flow into the Thames through the gravel, sand and made-up ground forming the overlying sub-soils. Of particular interest is the large water-bearing sand and gravel sub-soil in the St. Paul's area. As the Cathedral foundations do not rest on the London clay, it is essential for the safety of the building that no underground operations be carried out which would be liable to disturb the equilibrium of the water levels in the vicinity. It is for this reason that the St. Paul's Preservation Act of 1935 confers certain powers on the Cathedral Authorities to restrict the removal of sand and gravel and the pumping of water in what is called the "prescribed area."

Ordnance Datum.

Ground levels as shown on Ordnance maps, stratum levels and water levels are related to the Ordnance Datum which is the mean open sea level at Newlyn, in Cornwall, as computed from hourly observations taken over a period of six years from 1915 to 1921. The Datum level shown on old Ordnance maps refers to the Liverpool Datum which is 1·13 ft. below the Newlyn Datum, and was abandoned owing to the influence of the river.

Artesian Wells and Bore Tubes.

Shallow well water in the London clay area is taken from wells sunk to a depth above the top of the clay, but for deep well water, which is far less liable to contamination and more abundant, it is necessary to sink a bore through the clay into the pervious strata below. The Citadel Building, Faraday N.E. Block,

[1] *P.O.E.E.J.*, Vol. 38, p. 127.

[2] *P.O.E.E.J.*, Vol. 31, p. 265.

has its self-contained water supply from such a bore. A 12 in. steel tube is driven in to the chalk to a depth of 227 ft. below surface level and the bore is continued without a lining to a depth of 600 ft.; pumping is by compressed air as shown in Fig. 1. The delivery

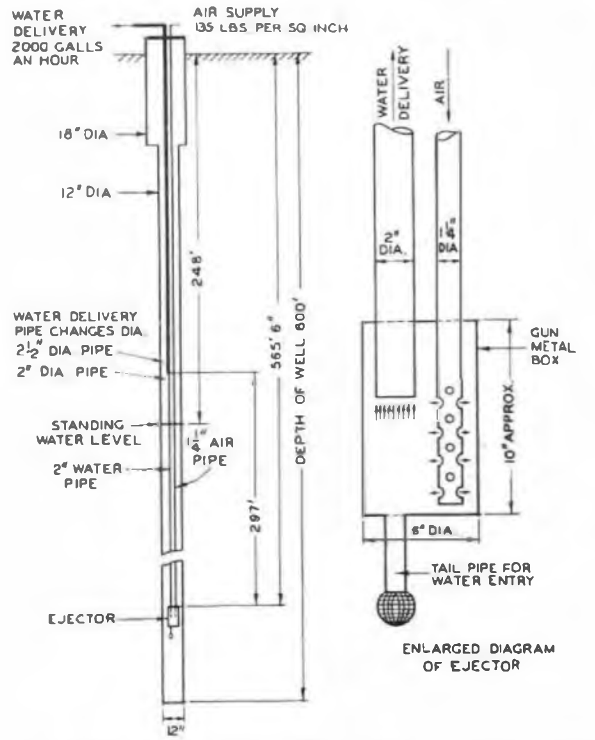

Fig. 1.—Faraday Building, N.E. Block. Artesian Well Ejector Diagram.

of a well pump is approximately proportional to the lowering of the water level caused when the pump is in operation and beyond certain limits is not increased by enlarging the bore.

For the boring operations, sheer-legs are erected over the site and the successive lengths of tube are screwed together (Fig. 2) and pile driven, a protective crown being screwed temporarily to the top of each length. The tube is driven a foot or so in intermittent stages between which the soil within the tube is broken down and formed into slurry by a wide chisel-shaped tool, sufficient steel rods being added from time to time to make up the requisite length. After the removal of the slurry by a valve-ended tubular bucket, the operation of driving is resumed; details of the two boring tools are shown in Fig. 3. A check on the verticality of the tube is made as the driving progresses by two discs attached concentrically to a plumb wire, the lower one having a bare clearance in the tube. The smaller upper disc is adjustable along the plumb wire and its eccentricity with the tube is a measure of the "out of plumb."

Steel bore tubes were driven in this manner from the Service departments and the Federal exchange to the deep level tunnel system, as in the original conception of the scheme it was intended only to provide cable routes from these buildings. The method of suspending the cables in the bore holes is referred to later.

Fig. 2.—Screwing in a Section of Bore Tube.

Preparation for Tunnelling.

The first essential in driving a tunnel is to survey the proposed route in relation to the positions decided upon for the shafts and any bore tubes that may be required, special care being taken to establish that

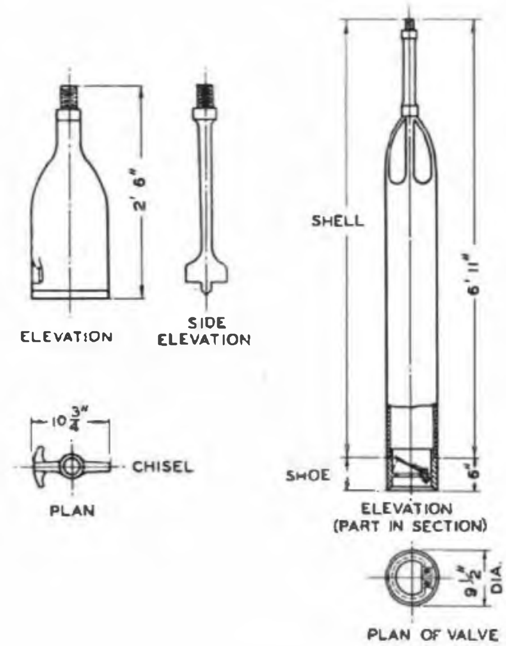

Fig. 3.—Boring Tools for 12 in. Diameter Bore Hole.

the tunnel will be clear of any obstructions, e.g., L.P.T.B. tubes and artesian wells. The complete information obtained from this surface survey is transferred later to tunnel level via two plumb lines down each shaft. When driving long tunnels, intermediate vertical working shafts slightly offset from the line of the proposed tunnel are provided to facilitate speed of completion, each additional shaft thereby affording two more working faces.

The sites for the shafts having been determined, it is usual for the Consulting Engineer to require test bores 6 in. diameter sunk at or near the shaft sites, to determine the thickness of the various strata and the water levels. This information is useful both as a guide for determining the limitations of the tunnel depth and also to ascertain whether the subsoil is sufficiently water bearing to require special precautions in sinking the shafts. It should here be mentioned that Sir Harley Dalrymple Hay continued to act as Consulting Engineer to the Post Office until his death in December, 1940, when he was succeeded by Mr. W. T. Halcrow, now Sir William Halcrow.

In sinking a shaft from ground level through water-bearing subsoil one of the following methods is adopted, depending on site conditions.

(1) Chemical consolidation, " Joosten " process.
(2) Cylinder sinking under load.
(3) Steel piling.

Chemical consolidation. This method was adopted in sinking to the level of the London clay most of the shafts for the Post Office tunnels, and is of general application where a shaft is to be sunk from within a building or in close proximity thereto. In addition to providing an impervious annular-shaped wall of consolidated subsoil within which the shaft may be sunk with a minimum of pumping, it avoids the risk of disturbance to nearby building foundations, particularly in areas where the subsoil is heavily waterlogged. By arrangement with the patentees, the " Joosten " process is carried out in England by Messrs. John Mowlem. Two chemical agents are employed, sodium silicate and calcium chloride, solutions of which are injected alternately into the subsoil, the resulting insoluble product, calcium silicate, forming the cementing agent.

Fig. 4 shows the operation in progress at Warwick Lane preparatory to the construction of the working shaft for the cable tunnel between Faraday Building and King Edward Building. The site of the shaft being within the " prescribed area " of St. Paul's and heavily waterlogged, particular care was necessary to ensure that the gravel and sand subsoil was thoroughly consolidated before excavation for the shaft was commenced. The injections were made at a pressure of 350 lb. per sq. in. through hollow steel rods driven into the soil by a compressor tool, each rod being perforated above the spike end. The sodium silicate was injected at the end of each downward drive of 2 ft. to clay level and the calcium chloride at similar stages during withdrawal. As each injection had an effective radius of 1 ft. and was applied at points on the surface 2 ft. apart round two concentric perimeters 12 ft. and 16 ft. diameter, a consolidated annular wall 4 ft. thick was provided within which the loose subsoil could be excavated for the 10 ft. diameter cast iron shaft.

In the construction of the shaft the top ring of segments was first assembled and suspended from cross beams. Successive rings were bolted on as the excavation work progressed, the space between the completed ring and the surrounding soil (the extrados) being grouted with neat cement through the grout holes in the centre of each cast iron segment. It is of interest to note that as the construction of a shaft proceeds downwards it gradually becomes self-supporting, thus enabling the supporting cross beams to be removed. All bolt heads and nuts are provided with washers and hemp grummets soaked in a mixture of red lead and boiled linseed oil and the segment joints are lead caulked to prevent the ingress of water.

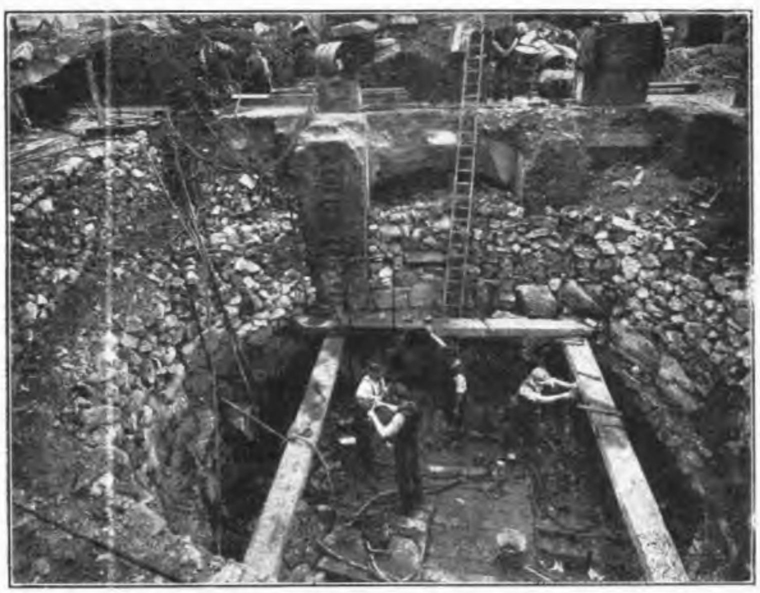

FIG. 4.—CHEMICAL CONSOLIDATION.

Cylinder Sinking under Load. This is a cheaper method than (1) and is usually employed on sites well away from buildings where the effect of a slight subsidence of the surrounding subsoil is not of serious moment. The shaft is built up over the selected site to a height rather more than the thickness of the permeable subsoil, a ring with a cutting edge being bolted to the bottom flange. This method was adopted (see Fig. 5) on a bombed site in Chancery Lane in the construction of one of the working shafts for the cable tunnel from Holborn exchange, which at its eastern end connects with the cable tunnel between Faraday Building and King Edward Building. The built-up section of the shaft was loaded with a weight of 45 tons, and the gravel and sand subsoil within removed by a crane and grabber ; this allowed the shaft to sink gradually into the clay bed. Continuous pumping enabled the shaft to be grouted and caulked after which construction proceeded downwards in the normal manner.

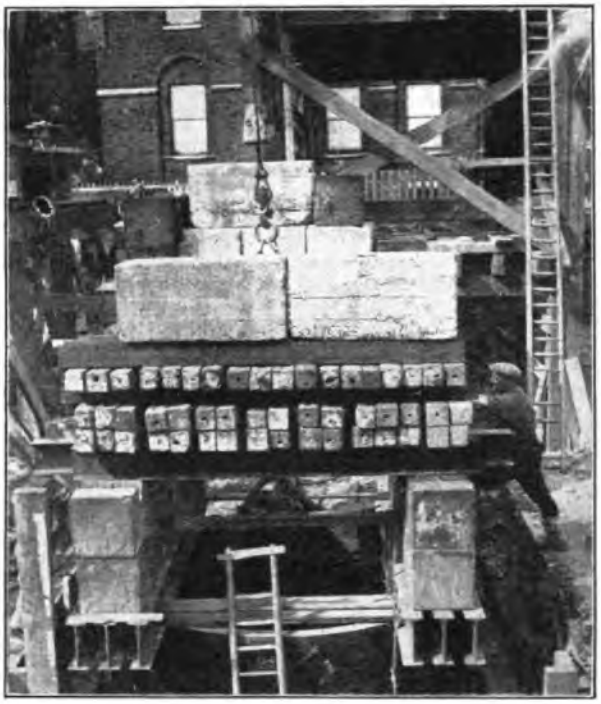

Fig. 5.—Cylinder Sinking under Load.

Steel Piling. To drive piles for a cofferdam of small diameter is not easy, and there is always the possibility of a pile coming out of its clutch. Moreover, leakage of water through the clutches may be considerable. This method is rarely adopted except for large sites.

Tunnelling.

Having reached the requisite depth at which the tunnel is to be constructed, it is necessary to establish a base line from which the underground survey is to be commenced and continued as the tunnelling work progresses. It will be appreciated that a high degree of accuracy is essential on both the surface and deep level surveys. The initial base line at deep level is barely equal to the internal diameter of the shaft, the plumb lines being dropped at opposite ends of the diameter which is in line with the direction the tunnel heading is to take.

Where sites for intermediate working shafts are available a quarter to half a mile apart and the tunnel is not more than 8 ft. in diameter, it is generally more expedient and economical to drive the tunnel entirely by hand. The shield, however, is a valuable aid in loose soil as it reduces or obviates the need for timbering, and used in conjunction with compressed air it is standard practice for excavating in water-bearing strata. By the use of an air lock, which is moved forward as the cast iron lining of the tunnel progresses, the air pressure in the tunnel heading is raised sufficiently to balance the head of water, thereby restraining the water from entering the heading. At comparatively shallow depths the miners work with little inconvenience, but at depths where the requisite air pressure may reach as much as 35 lb. sq. in. the men are able to work for short periods only.

The Post Office tunnels were driven entirely within the London clay and no special precautions were necessary to deal with the seepage due to cracks and fissures in the soil. All were hand-driven with the exception of one of 12 ft. diameter and 620 yds. long, where shields were employed to facilitate completion. The working shaft for this tunnel, which was driven at a depth of approximately 100 ft., was sunk near the mid-point, and at the end of a short approach tunnel a 15 ft. diameter double-shield chamber was constructed, the ends of the chamber being close timbered against the clay while the shields were being erected.

Fig. 6 shows one of the "Greathead" shields being built up in the shield chamber. This type of shield consists essentially of a cylindrical tube of steel plating 3 ins. larger in diameter than the tunnel lining and adequately stiffened against the external pressure of the soil. The front rim has a cutting edge and a diaphragm plate is fitted through which an opening gives access to the working face. Multiple doors or sliding shutters are provided in shields of large diameter. The shield is driven forward in stages for a distance equal to the axial length of a ring of cast iron segments by 10 hydraulic jacks placed round the inner circumference of the tube and parallel to the tunnel axis, the thrust being taken by the exposed flange of the ring of segments last erected. At the end of each forward drive hand excavation within the front end of the tube is carried out with the aid of pneumatic picks or spades as best suited to the particular soil,

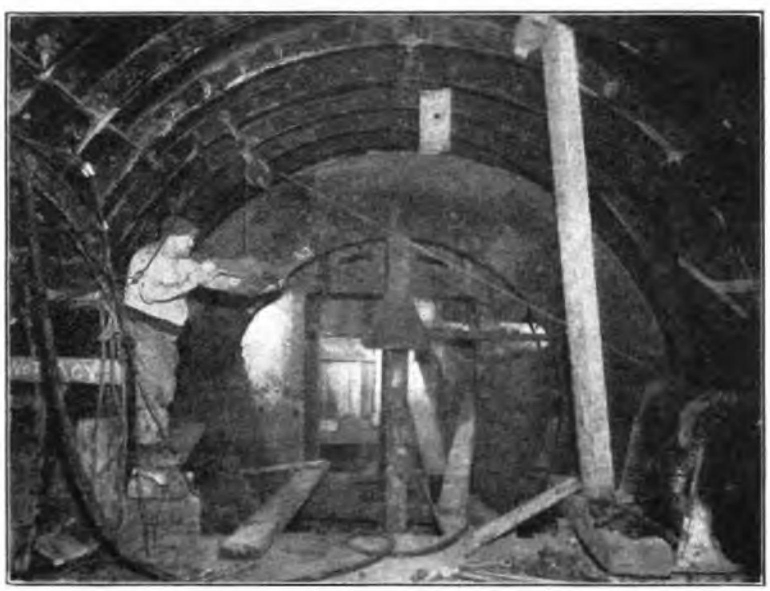

Fig. 6.—"Greathead" Shield being erected.

the latter being used in dealing with the London clay. After the pressure on the rams is released, the next complete ring of cast iron segments is built up under cover of the back of the shield which is free from any internal bracing. The jacks are then transferred to the newly completed ring, and the next forward drive moves the shield clear of the extrados which is then grouted under pressure with neat cement through the segment holes, the leading end being plugged with clay to prevent the cement exuding. A record of the line and level of the shield is maintained, any correction that may be necessary being made by an adjustment of the jacks. It will be noted that this type of shield does not remove the soil but provides a cylindrical bore within which the excavation at the heading is carried out by hand-operated tools. The rotary type of shield, however, combines a rotary excavator with a shield of the "Greathead" type.

For the removal of the spoil to the working shaft and the transport of the tunnel material a temporary runway is laid on sleepers placed across the tunnel segments, the trucks being run in conjunction with a crane at the head of the shaft.

Tunnelling, except in hard rock, is normally carried out as a continuous operation, as it is undesirable to keep a heading exposed longer than is necessary. The rate of progress at each face for a 7 ft. diameter C.I. tunnel hand-driven in the London clay was about 75 ft. per week. The use of shields increases the rate of progress to about double that for hand tunnelling, but this is offset to some extent by the time occupied both in the construction of the shield chamber, which is of larger diameter than the tunnel, and the erection of the shields.

At points along a tunnel where a change in diameter occurs, e.g., at each end of an enlargement chamber, the junction is effected by thick concrete headwalls which surround two segment rings in each direction. Fabricated steel and concrete junctions are made at points where laterals enter the main tunnels.

At the bases of the permanent shafts associated with the Post Office tunnels enlargement chambers have been provided, the increased diameter being effected by conical-shaped segment rings. The increased space thus afforded has proved of great advantage in handling cable drums, conduit and bulky equipment.

Jointing of Tunnel Segments.

The backs of the segment flanges forming the longitudinal joints of cast iron tunnels are machined, and in order that the rings may be assembled, one of the flanges of the key piece incorporated in each ring is suitably inclined to the radius of the tunnel: the abutting flange of the next segment is similarly inclined, but all other longitudinal flanges are radiated to the centre of the tunnel. The rings are assembled without any jointing material between the machined faces, but the circumferential flanges which are not machine faced have creosoted wood slats inserted, and these are firmly compressed when adjacent rings are bolted together. All flanges are shaped so as to leave a caulking groove when the segments are bolted together. Grummets soaked in a mixture of red lead and boiled linseed oil are provided under the head and nut washers of the bolts. In dry situations the caulking grooves are filled with cement compo, but in wet situations the joints are caulked with lead and the filling completed with a rust composition of iron filings and sal ammoniac. Lead caulking, however, is a laborious process and adds considerably to the cost of a tunnel. In one of the Post Office tunnels a saving was effected by lead caulking the upper half of the tunnel and inserting "U"-shaped channel strips in the caulking grooves of the lower half to lead the drainage from the back of the segments to the tunnel invert; the filling of the grooves was then completed with cement. The problem of water seepage into a tunnel in wet or even damp situations is, indeed, one of considerable difficulty and an entirely satisfactory solution has yet to be found.

Reinforced Concrete Tunnels.

Precast reinforced concrete segments are sometimes used in lieu of cast iron but this form of construction is suitable only in dry situations. The skin and flanges of the segments being thicker, the size of the tunnel is correspondingly smaller than a cast iron tunnel for the same amount of excavation. There is no caulking groove in the flanges and longitudinal joints are formed by placing bituminous sheeting between the flanges to their full depth. For the circumferential joints, a layer of tarred rope yarn is inserted between the bolt circle and the outer circumference of the segment rings. Dry hemp yarn grummets are placed under both head and nut washers, and all joints are finished with cement pointing. A completed section of the 7 ft. diameter R.C. tunnel under Holborn is shown in Fig. 7.

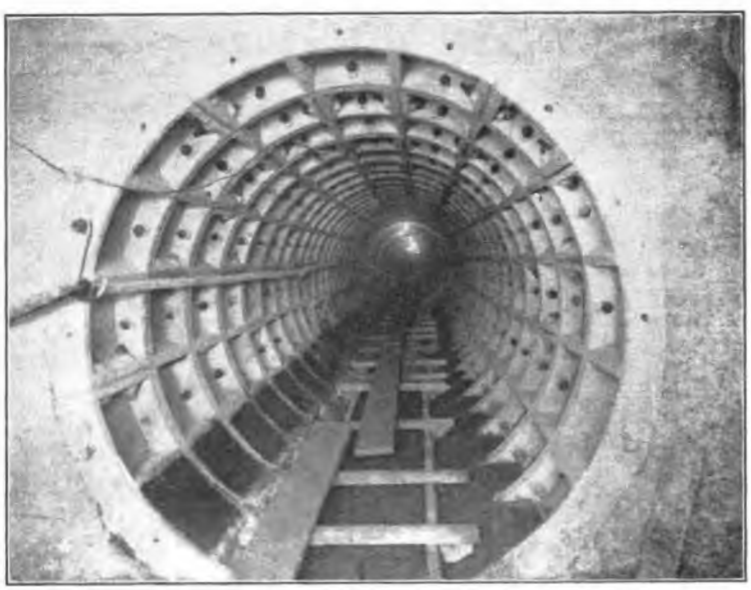

FIG. 7.—REINFORCED CONCRETE CABLE TUNNEL.

Standards of Transmission and Local Line Limits

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U.D.C. 621.395.1 621.395.8

Part 1. Factors Affecting the Transmission of Speech over a Telephone Circuit

This is the first of two articles dealing with the transmission of speech over a telephone circuit and the various methods of assessing standards of transmission. Part 1 reviews international commitments and methods of assessing earlier standards and describes the factors affecting the transmission of speech and those parts of the circuit concerned. Part 2 will deal with the effect of the overall frequency response and describe the " effective transmission" method of calculating the ratings of local circuits.

General.

IN any telephone system, comprising a network of telephone exchanges (interconnected by junction and trunk circuits) to which are joined a number of subscribers' stations, it is obviously essential to maintain a close control over efficiency of transmission. Such control is required to operate nationally and internationally. There is in force at present an international agreement relating to standards of transmission in Europe, and Great Britain is bound by this agreement which specifies the worst overall transmission condition which is tolerable. Clearly the factors which control transmission over an international connection will be the performances of the subscribers' sets and lines used for the connection and will therefore be split up between the plant of the administrations of the various countries concerned in the connection. The international agreement takes account of this fact and breaks down the overall limit (end to end) into limits which relate to single administrations.

The various administrations are at liberty to design their own telephone networks (so as not to exceed the agreed tolerable limit) in any manner which suits them; that is to say, they are free to adjust the absolute electro-acoustic efficiency of their subscribers' sets, their subscribers' line losses, their junction losses and their trunk losses in any one of an almost infinite variety of possible permutations.[1]

Present-day designs have evolved over a period of time from an initial design which was largely dictated by the maximum subscriber's set efficiencies available at that time. In this country, the available economic and stable sets were those using the " solid-back " (C.B. No. 1) transmitter and the Bell receiver. They were used for many years and a large line network was installed, with reasonably economic distribution of total allowable attenuation between trunk lines, junction lines and local lines, to a design which was based on what were for many years the unalterable characteristics of these sets. Changes in sets have of course, occurred since these early days of initial design and considerable alterations in methods of usage of line plant have become available. However, a line network for a telephone system, once installed, can be changed only at a very slow rate and many of the present-day controls on line layout are thus inevitably still linked back to the early design.

Standards of transmission have been for many years (and, indeed, still are) expressed on a " volume basis." Two telephone connections are said to have equal " volume efficiency " if they sound equally loud to an average observer when each is spoken into in precisely the same manner. An international standard of volume efficiency is maintained in a laboratory in Paris in the shape of a carefully maintained, and very stable, transmission system known as the S.F.E.R.T. Practical systems are " rated," in terms of this standard, as being X db. more or less efficient than the reference system. The figure X db. is known as the " reference equivalent " of the practical system. The internationally agreed lower limits of transmission efficiency are expressed in terms of reference equivalent and each administration must necessarily know the reference equivalents of its worst combination of subscriber's set and subscriber's line, its worst junctions and its worst trunks to be able to keep its part of the international agreement.

It is an experimentally proved fact that the reference equivalent of any junction or trunk line is sufficiently well defined by its attenuation measured at 800 c/s, but the reference equivalent of a combination of subscriber's set, subscriber's line and exchange equipment must essentially be measured by direct voice-ear comparison with the reference system.

Standards of transmission for this country were originally formulated in 1905; the lower limit tolerable for the efficiency of the combination of subscriber's set, subscriber's line and exchange equipment being included in these standards. It was then agreed that no such local circuit should give transmission inferior to that obtained with a standard subscriber's set (Transmitter C.B. No. 1, Bell receiver, 17+26 ohms induction coil, 2μF condenser and 1,000 ohms bell) operating over a 300 ohms non-reactive local line to a 22V C.B. No. 1 exchange (No. 25C repeating coil and 30+70 ohms shunt relay). A close approximation to this limit for local transmission has been preserved, on a volume basis, ever since 1905. New transmitters, receivers, induction coils, exchange circuits, etc., have all been assessed in terms of their effects on the volume efficiency of the circuit, and new limits of line length have been calculated to take advantage of better equipment, but always within the limits set by the originally agreed lowest tolerable volume efficiency (measured as a reference equivalent). Thus, for example, an average Tele. 162 with Bell Set No. 25, operating over 450 ohms of 10 lb. cable to a 50-volt, 200+200 ohms, Stone circuit exchange gives transmission just equal to the lowest tolerable limit.

A number of difficulties have been encountered in the maintenance of even such a very simple

[1] *I.P.O.E.E.* Printed Paper No. 88.

standard. Limits must obviously be set for both sending and receiving and the choice of the relative sending and receiving sensitivities of a subscriber's set is not automatically imposed by a choice of transmitter and receiver. Within limits it is possible economically to vary the relationship between the two sensitivities by choice of design of induction coil. Any single choice of design may suit the average of a large number of conditions of line impedance (from the point of view of matching load and generator impedances) but will obviously not be optimum for each individual condition. This fact has resulted in some difficulty when transmission limits are expressed (as they essentially must be for design purposes) in terms of the maximum permissible line length tolerable with a given combination of set and exchange. It is common to find that limiting transmission in, for example, the "send" direction to the exchange is reached with a shorter length of line than would be tolerable in the "receive" direction from the exchange. In such instances engineering practice in this country has evolved the common-sense procedure of accepting the smaller of the two limiting line lengths so calculated for application to problems of network design.

For some years now it has been fully realised that the volume standard, valuable though it is as a standard, does not take account of all the effects which react upon the true transmission efficiency of a circuit. The demand for sheer volume, without any specific standard of quality, is bound to be open to this criticism. An assessment of the quality of the transmitted speech can be made by some form of articulation test in which the number of sentences, words, syllables or sounds correctly received over one circuit is compared with that received over a standard or the reference circuit[2]. Another method used in this country is known as "immediate appreciation" and in this, the percentages of simple sentences, the meanings of which are immediately perceived without conscious effort, are compared.[3, 4]

It can be shown theoretically and by test that the results obtained by all of these methods are closely related. The choice of method for any particular test depends therefore on which is the most suitable for the conditions under which the test must be made. The method most generally used is that in which the percentages of meaningless syllables, known as logatoms, correctly received is recorded.

The effect of the introduction or removal of any factor which causes a degradation or improvement in transmission may be measured by the alteration in articulation which ensues. In practice, a more convenient method is to measure by articulation tests or any other convenient method, the change in non-reactive attenuation which will restore the original overall grade of transmission. The equivalent attenuation at all frequencies introduced or removed by the change can then be estimated in decibels. An illustration of the results obtained is shown in Fig. 1 for three different test conditions[2]. Curve A relates to the initial condition. Curve B illustrates that the effect of making a certain change results in improved articulation when the circuit attenuation is low but worse articulation when the circuit attenuation is high, whereas the change illustrated by Curve C results in a general improvement in articulation over a wide range of received speech levels.

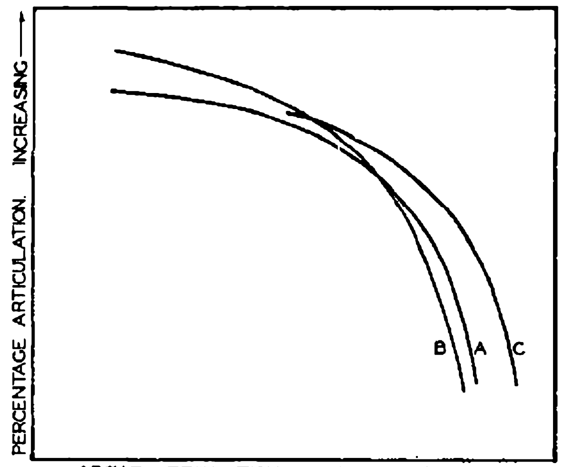

Fig. 1.—Relation between Articulation and Circuit Attenuation.

The Post Office has, for many years, taken considerable account of quality of reproduction when purchasing new transmitters and receivers and when installing new junction and trunk circuits, but such account has been qualitative rather than quantitative. It has not been reflected in line network design and cannot be taken into account in the strict application of internationally agreed transmission standards. Other controlling factors, such as sidetone and room noise, are also neglected and the accurate assessment of the relative efficiencies of equal lengths of different gauge subscribers' cable circuits has, in consequence, not been possible.

A method of taking more realistic account of all the factors controlling local transmission has now been developed and will be applied to Post Office design work. It is known as the Effective Transmission method; the main purpose of this article is to describe the method and its proposed application to Post Office engineering practice. Before this is done, however, it is essential that the reader should be reminded that the application of the method is a purely national concern related to the design of the British network. The British Post Office is still bound by the international volume limits and must continue to honour its agreement in this respect. The application of Effective Transmission is therefore limited to its use as a more realistic and informed design procedure for the national network within the limits set by the international volume standards.

Factors affecting Overall Efficiency.

The various items of apparatus associated with a typical junction call together with their effect on the transmission of speech, are enumerated in Table 1 and considered separately afterwards.

[2] *P.O.E.E.J.*, Vol. 31, p. 286.
[3] *B.S.T.J.*, Vol. 8, Oct., 1929.
[4] *Siemens Engineering Supplement*, No. 140.

TABLE 1.
CALL FROM SUBSCRIBER A (SPEAKING) TO SUBSCRIBER B (LISTENING) VIA A JUNCTION.

Item	Apparatus	Factors affecting the Transmission of Speech
Subscriber's Station A	Subscriber's Set (Transmitter, Receiver and Induction Coil)	Sending Efficiency, including non-linear distortion Sidetone
Subscriber's Line A	Cable or Aerial Line	Transmission Loss Line Noise
Exchange A	Transmission Bridge Battery	Transmission Loss Feeding Current Exchange Noise
Junction	Cable or Aerial Line Any intermediate apparatus	Transmission Loss Line Noise
Exchange B	Transmission Bridge Battery	Transmission Loss Feeding Current Exchange Noise
Subscriber's Line B	Cable or Aerial Line	Transmission Loss Line Noise
Subscriber's Station B	Subscriber's Set (Transmitter, Receiver and Induction Coil)	Receiving Efficiency Sidetone Room Noise

Subscriber's Station.

The parts concerned with the transmission of speech are the transmitter, receiver, induction coil and condenser. Items provided for signalling purposes such as switch-hook contacts, bell and dial, have no appreciable effect on transmission unless faulty.

Both the transmitter and receiver are energy converters in that they effect an interchange between speech sound pressures and electrical signals. In practice, no attempt is normally made to determine their absolute efficiencies, and instead, the power output of the subscriber's set is measured relative to that of a standard under specified conditions, thereby enabling the sending rating and the receiving rating to be deduced. Both the sending and receiving ratings are normally expressed in decibels (db.) and are considered to be positive if the test item is better than the standard.

It is obvious that, generally, the more efficient a transmitter or receiver is, the better result it will give in service. The transmitters at present in use (Insets No. 10 and 13), although possessing a high efficiency, suffer from the disadvantage of carbon microphones of this type that the electrical output is not directly proportional to the sound input level. The practical effect of this non-linear distortion is to produce harmonics of the lower speech frequencies and these harmonics tend to mask higher frequencies normally present in the speech, resulting in a loss of clarity or articulation.

In the telephone receiver the sound output at any frequency varies almost directly with the electrical input, but owing to its being an electro-magnetic device, its impedance and efficiency vary considerably with frequency. The direct result of this is that the efficiency of the subscriber's set varies with frequency, both for sending and receiving. Consequently, the subscriber's set contributes largely to the overall frequency response of the system, the effect of which is dealt with in Part 2.

Exchange switching difficulties and line plant economics at present preclude the use of 4-wire circuits from subscriber to subscriber, and consequently a compromise has to be made by the use of an induction coil interconnecting the transmitter and receiver to the 2-wire network. The primary purpose of the induction coil is to afford a degree of impedance matching between the transmitter, line and receiver to enable the optimum transfer of energy to be obtained between the transmitter and line for sending and between the line and receiver for receiving. Secondary functions are (*a*) to provide a means of

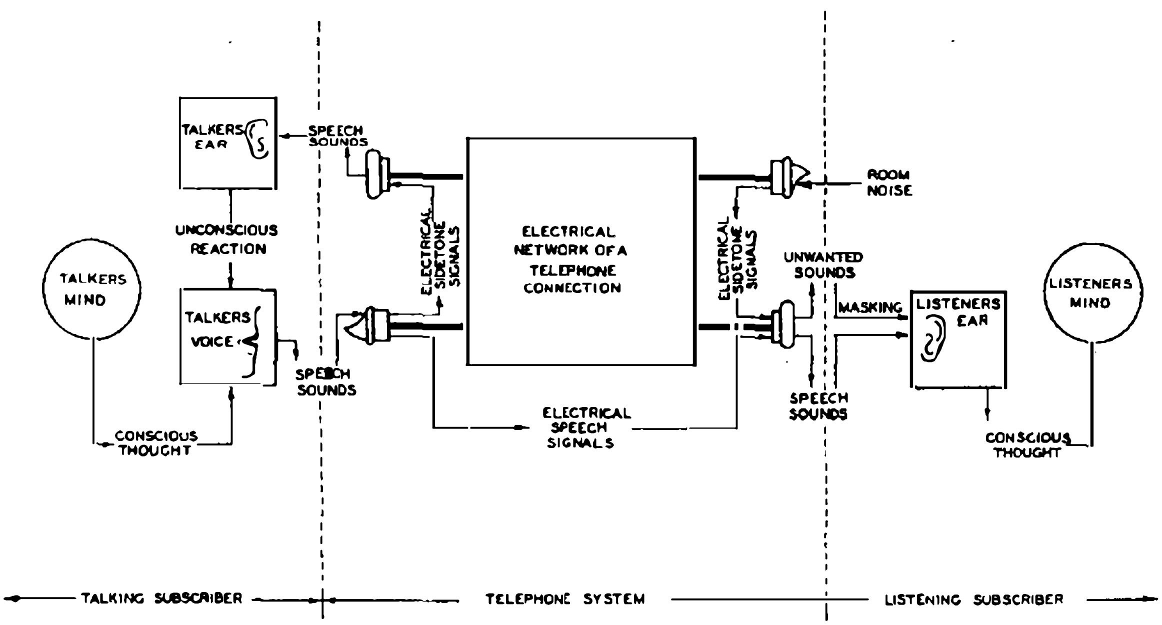

FIG. 2.—COMMUNICATION OF INTELLIGENCE VIA A TELEPHONE SYSTEM.

increasing the sending efficiency at the expense of the receiving efficiency or vice versa and (*b*) to enable sidetone to be reduced with advantages to transmission which are dealt with later.

In the same way as a hybrid transformer acting as a 4-wire termination at the end of a trunk circuit introduces a loss in both directions, the subscriber's set using an induction coil is less efficient than if designed for 4-wire working. Part of the incoming energy from the line is now dissipated in the transmitter circuit and part of the outgoing energy from the transmitter is wasted in the receiver (as sidetone) or in the sidetone balance circuit where the induction coil is of an anti-sidetone type (A.S.T.I.C.).

An important incidental phenomenon associated with the use of an induction coil in the subscriber's equipment is known as sidetone and results from the introduction of a leakage path between the transmitter and receiver. This appreciably affects the transmission path from one subscriber to the other by virtue of their psychological reactions, which are depicted in Fig. 2.

The voice level in ordinary room conversation is normally controlled by the talker hearing his own voice and adjusting the level to an accustomed loudness. When a telephone receiver is placed on the ear, the natural sidetone path through the air is interfered with and the talker reacts unconsciously to the sidetone level that is heard in the receiver via the electrical path. Increase in sidetone level will cause the speaker to lower his voice and will consequently be equivalent to a loss in sending efficiency, as illustrated by curve S of Fig. 3.

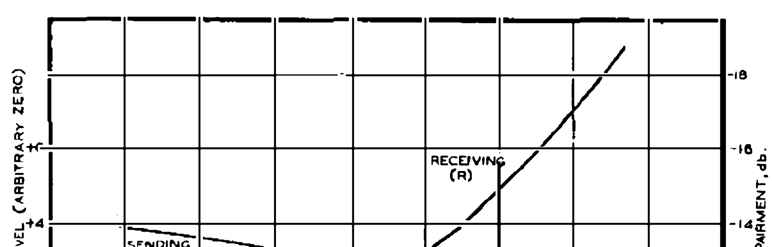

Fig. 3.—Relation between Room Noise, Sidetone and Transmission Loss.

Sidetone also has an effect on the subscriber who is listening. Room noise will agitate the transmitter and being heard in the receiver via the sidetone path of the telephone, will tend to mask the received speech. Increase in sidetone level will therefore be equivalent to a loss in receiving efficiency. The amount by which the received level must be altered to give equality of reception as the sidetone level is varied is shown by curve R of Fig. 3. This curve (and curve S to some extent also) will be modified by the level and character of the room noise present.

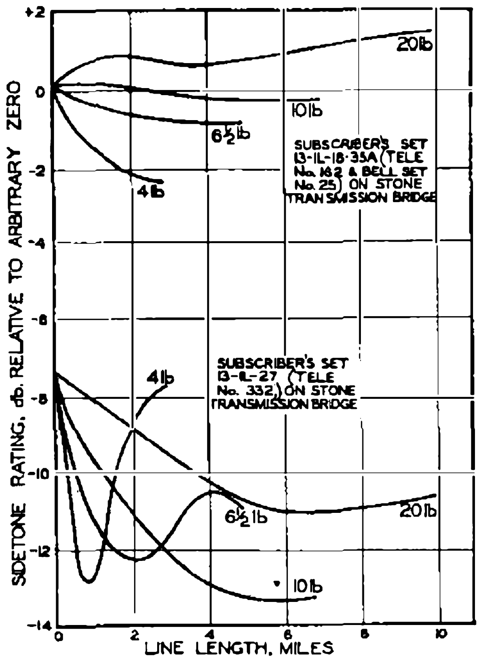

Fig. 4.—Variations of Sidetone Ratings with Length of Local Line.

The level and frequency spectrum of the sidetone will depend upon the sensitivities of the transmitter and receiver, upon the design of the induction coil and sidetone balance circuit (if any), and upon the impedance of the line to which the telephone is connected. The line is normally capacitative (although it varies in impedance and angle from call to call), but the instrument is inductive and consequently impedance variations in opposite directions occur with changes in frequency.

Curves showing how the sidetone varies for Teles. No. 162 and 332 are shown in Fig. 4. As the subscriber's set may contain any one of several different types of transmitter insets, receivers or induction coils, it is now specified by a code which completely describes the set. Thus in Fig. 4, 13—1L—18·35A means any set having a Transmitter Inset No. 13, a Receiver No. 1L, Coil Induction No. 18 with Transformer No. 35A, together with a 2 μF capacitor and 1000 ohms bell, i.e. a Tele. No. 162 C.B. or Auto and Bell Set No. 25. A Telephone No. 332 is similarly designated 13—1L—27, if containing a Coil Induction No. 27.

The speech voltage sent to line (and also the sidetone level) will depend upon the magnitude of the direct current feeding the transmitter and the " feeding current effect " is defined as the ratio of transmitter output P.D. with a given magnitude of feeding current to that with a standard value of feeding current. The result is expressed for any given subscriber's set using a specified value of line impedance. The effect includes those due to the change in transmitter E.M.F. and also the simultaneous change of transmitter resistance.

The "sidetone level" is equal to the sidetone rating plus an allowance for the feeding current effect and any increase in sidetone is considered as a positive change in rating or level. The "sidetone effect" is defined as the amount of non-reactive attenuation which must be inserted in or removed from a telephone circuit to have the same effect on overall articulation as a change from the standard sidetone level to that under consideration. The comparison is made under specified room noise conditions.

The effect of changes in line current on output, in the Tele. No. 162 circuit (in which the inset is shunted by the 175-ohms winding of the Transformer No. 35A) is illustrated in Fig. 5. The current in the subscriber's

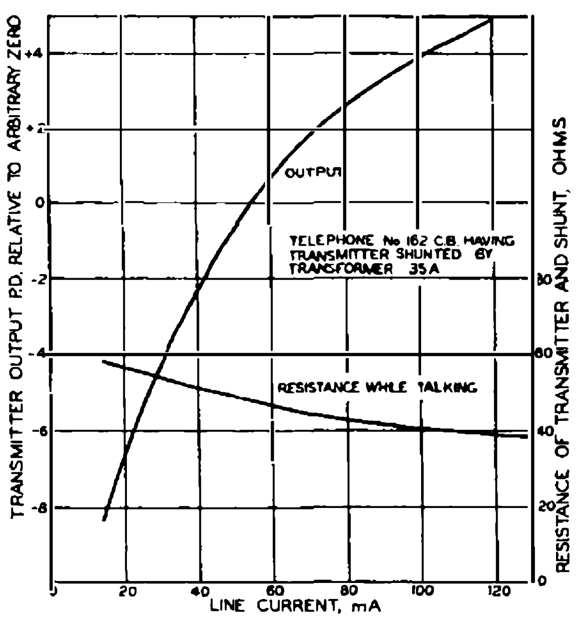

FIG. 5.—RELATION BETWEEN OUTPUT, COMBINED RESISTANCE AND LINE CURRENT.

line is usually between 30 and 190 mA and will be determined by the exchange battery voltage and the total resistance of the circuit, i.e. exchange feeding bridge (including ballast resistor if present), line, induction coil line winding and the parallel resistance of transmitter and shunt (if any). The resistance of the transmitter will also vary with current. An average curve for a Tele. No. 162 C.B. or Auto, in which the transmitter is shunted and the transmitter current is less than the line current, is also shown in Fig. 5.

The speech voltage sent to line will also depend upon two factors over which there is no appreciable control, namely, the subscriber's normal voice and the distance from the mouthpiece at which the subscriber speaks. In actual practice, further losses may be caused by series apparatus or bridging effects where P.B.X.s are installed or certain extension arrangements are employed.

Subscriber's Line.

The subscriber's line usually contains a length of cable, though much overhead line is still in existence. The attenuation of either type of line becomes greater as the frequency increases with the result that the received speech level falls off more at the higher frequencies as the length of the line increases. The relative importance of these higher frequencies in the transmission of speech is dealt with in Part 2.

The effect of line noise is partially to mask the received speech. The magnitude of line noise in practice is such that the degrading of transmission is generally small compared with that caused by the other factors present. With the extension of the upper frequency response of new types of receiver, this may no longer hold and the importance of line noise will need to be reconsidered.

The "subscriber's line rating" is defined as the difference (in decibels) between the transmission loss of a given subscriber's line and that of a standard subscriber's line. The test is made under specified conditions of subscriber's set, exchange and junction.

Exchange Equipment.

The only item of exchange equipment which affects transmission on the vast majority of calls is the transmission bridge. The function of this is to supply direct current to the subscriber's line for the purpose of signalling and (except in L.B. cases) to provide feeding current to the carbon transmitter of the subscriber's set.

The transmission bridge causes an A.C. insertion loss in the speech circuit of about 0·5 to 1 db. This loss varies with frequency and therefore affects the response of the overall circuit.

The "transmission bridge rating" is defined as the difference (in db.) between the transmission loss of a given bridge and that of a standard transmission bridge. The "relative circuit rating" is defined as the send (or receive) rating of a subscriber's set plus the rating of a given exchange transmission bridge.

Junction.

As with a subscriber's line, a transmission loss which varies with frequency is introduced by an unloaded junction. Where the junction is of loaded cable, the loss will be practically constant up to the cut-off frequency. The junction therefore affects the overall attenuation of the circuit and also, in the majority of circuits, its frequency response.

Line noise on the junction will degrade reception in the same way as noise on the subscriber's line.

A trunk call can be regarded as equivalent to a junction call by including the loss between the terminals of the trunk network with that caused by the junction. The trunk network is designed for an overall A.C. loss of zero db. but, in practice, degrading of speech transmission may be caused by echo, echo-suppressors, repeater noise, line noise, variation in gain of repeaters and limitation of frequency response due to loading and other causes.

The Inland Transmission Testing Room at the London Repeater Station

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This article gives a brief description of the equipment recently installed in the Inland Transmission Testing Room at the London Repeater Station, Faraday Building, South, and outlines the considerations which made it necessary.

History.

THE installation of telephone repeaters in London during 1926 saw the commencement of the growth of the public trunk telephone network which was to increase in ever-lengthening strides. The original installation was in Faraday Building, North, known at that time as G.P.O. South.

The inauguration of the trunk demand service in 1932 brought about a further increase in new trunk lines to all parts of the British Isles. This increase had been partly provided for by the installation of repeaters on the ground floor of the Wood Street building in 1930. Later, in 1935, a new and larger repeater station was installed in Faraday Building, South. During 1937 the first 12-channel carrier systems to be installed in London were brought into service. From a few groups these grew to over a hundred working groups by 1939.

The introduction of the standard cheap night rate also brought about a rapid increase in the number of trunk lines. To provide this popular service, which became the heaviest peak load of the 24-hour period, and to maintain even a semblance of a demand service, many new lines had to be provided; even to the extent that renters' private wires, which were known to be in use only during normal business hours, were pressed into service at night on a part-time basis to provide additional outlets to provincial towns. All the work involved in the above had to be dealt with by the repeater station maintenance staff, which was expanded to meet this work. This meant that more than 50 per cent. of the available testing equipment was in constant use for lining-up new and rearranged circuits.

Up to 1938 the repeater station was controlled by one Inspector responsible for both maintenance and the provision of new lines (generally referred to in a repeater station as "Works Orders"). The work was then divided between two groups, one the "Maintenance" group and the other the "Works Order" group. Both these groups made use of the measuring equipment mounted on the test racks and this resulted in congestion.

The political situation in Europe towards the end of 1938 provided much work in the provision of emergency arrangements, etc., and the outbreak of war in 1939 caused a considerable increase in defence circuits and the replacement of traffic circuits taken for defence purposes. This resulted in an enormous amount of additional work, and to cover this increase the staff was augmented and a Control was set up to deal with all circuit advices. These include :—

Forms	A 886	Repeatered circuit advice,
,,	A 887	Non-repeatered circuit advice,
,,	E.-in-C. 608	Telegraph circuit advice,
,,	A 674	Alterations in traffic sequence of circuit.

In 1941 the number of circuit advices to be dealt with was so great that a separate group was set up to deal with circuit provision and rearrangement work. This group was known as the "Works Planning Group" (no confusion arose as normal "Works Planning" with reference to construction work was not operating in the area) with a Chief Inspector as Regional Liaison Officer having direct access to the Engineer-in-Chief's, Regional and Area Controls. (Fig. 1.)

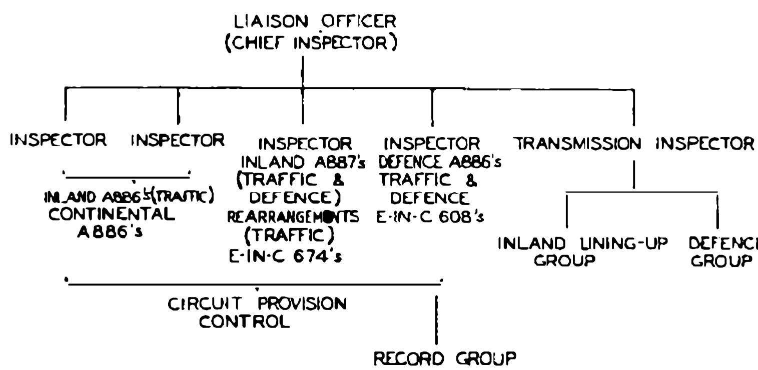

FIG. 1.—WORKS PLANNING GROUP.

Meanwhile in 1940 when France was occupied by the Germans the opportunity was taken of using the Continental test room exclusively for the "Works Order" staff. The transmission measuring sets in this room are all calibrated in népers for Continental working and all measurements had to be converted to the decibel notation before being recorded on the appropriate forms and cards. The use of this room was found to be a very satisfactory arrangement, in that the majority of the staff worked together free from interruptions and this had the effect of improving output. It was realised that although this arrangement satisfied the requirements for the time being it could not continue indefinitely.

The military situation towards the end of 1944 indicated that the resumption of Continental communications could not be far distant. It would then be necessary to make suitable arrangements to re-accommodate the staff engaged in "Inland" lining-up. Sketches were prepared, and with the aid of suggestions from the staff, a provisional scheme was evolved.

It was decided to retain the existing arrangement of the group whereby it functioned purely as a transmission control for setting-up and rearranging repeatered circuits. The various stations in Faraday Buildings (detailed below) are treated as through stations, all setting-up and adjustments being carried out by the respective station staffs; circuits being extended over test junctions from the line break-jacks of the trunk test racks.

In January, 1945, the final scheme was agreed and the work put in hand. In August, 1945, the new equipment described below was brought into use and all " lining-up " work is now carried out from the Inland Transmission Testing Room.

Design Problems.

Before dealing with the considerations leading up to the layout of the equipment it should be noted that at present an average of nearly 650 circuit advices are dealt with by the Long Distance Area each month: of these approximately 98 per cent. are circuits which are controlled, for transmission purposes, by London. It may be of interest to give briefly the layout of the apparatus and manner in which the work is dealt with in the area (i.e., within Faraday Buildings).

The apparatus is accommodated in a block of four buildings known as Faraday Building North, South, North-East and South-East (codes respectively are L/N, L/S, L/NE and L/SE). The equipment to line, viewed from the break-jack is situated as follows :—

LONDON NORTH.

London North Trunk Test and transformer racks for L/S Repeater Station M.U. cables.

LONDON SOUTH.

3rd Floor.—Repeater Station which includes Audio, Carrier Systems Nos. 2 and 4, and London-Birmingham (Tubes 1 and 2) co-axial equipment.

4th Floor.—Voice Frequency Telegraph Terminal.

5th Floor.—Carrier Terminal (Systems Nos. 5, 6 and 7).

LONDON NORTH-EAST.

London North-East Trunk Test, London North-East Repeater Station, which includes Audio, Carrier Systems No. 2 and 7, also London-Birmingham (Tubes 3 and 4) and London-Salisbury coaxial equipment.

LONDON SOUTH-EAST.

Toll Test racks and M.U. cables.

Cables carrying repeatered circuits terminate in all the above places.

From this it can be seen that the make-up and routing of a circuit within this Area can be very complex. To assist in maintaining some uniformity it has been ruled that for London controlled trunk circuits the location of the 2-wire ends will be determined by the location of the repeater apparatus. Thus, if the repeater apparatus is situated in L/S (including the Carrier Terminal), the 2-wire end terminates on L/S test racks, and if in L/NE, then the 2-wire end terminates on the L/NE test racks. The only exceptions to this rule are defence circuits and Renters' lines, which all terminate on the L/N test racks. On toll circuits (excluding those in the trunk exchange multiple) the 2-wire ends terminate on the L/SE test racks (excepting certain Toll " B " circuits into the trunk and toll director automatic equipment, which appear in L/N test racks) irrespective of the location of the repeater apparatus.

To co-ordinate and supervise the work efficiently it is desirable for it to be under the control of one group and the lining-up to be carried out from a central point, the repeater stations at Faraday Buildings being treated as intermediate stations. As already mentioned, from 1941 to 1945 all 4-wire lining-up measurements were carried out from the Continental test room over test extensions to the repeater station and carrier terminal in L/S. Occasionally, owing to the extreme pressure of work, one or more of the transmission measuring sets in the repeater station (L/S) had also to be utilised. In L/NE repeater station the lining-up was carried out from the 2-wire end via test extensions from the L/NE trunk test. The final overall frequency response, signalling and speaking tests, in all cases, being completed from the break-jack on the test racks extended over a test extension.

Experience gained in the Continental test room has shown that full D.C. testing equipment is essential, not only for testing and locating faults on D.C. signalling paths (of which considerably more use is now being made) but also for general testing. By the use of patching a definite test can be obtained. This has been found to be more satisfactory than the use of a tone when testing to intermediate testing points where A.C. testing facilities are not available (i.e. other than repeater or amplifier stations).

From the above it will be appreciated that the experience of the past few years has indicated that in order that one officer may control the complete work from start to finish of any group of circuits his test rack must have :—

Full A.C. testing facilities
Full D.C. testing facilities
Access via test extensions to all testing points within Faraday Buildings.
Speaking facilities to repeater speaker network, local public network, trunk and toll network, area sub-works order groups via direct speakers.

The following features were included in the equipment and final layout, viz. :—

(*a*) Ease of operation.
(*b*) Easy access to all associated apparatus.
(*c*) Clear uninterrupted view of all meters free from shadows cast by projecting equipment and cords.
(*d*) Robustness of equipment, clean appearance, easy to maintain and free from unnecessary detail.
(*e*) " Unit Bay " construction.

During the consideration of the layout of the equipment it was decided that it should conform as nearly as possible to the normal layout of standard apparatus racks, bearing in mind the special features of the equipment to be used.

It was not possible to adhere absolutely to standard layouts as, owing to the urgency with which the equipment was required, it was decided that items obtainable from the Post Office Stores Department should be used wherever possible. Thus as bus-bar assemblies were not available a system of power cables with teed joints was used. These cables were distributed underneath the cable runway over the bays, being held in position by clips designed locally, and tee joints made to connect the filament, relay, plate and 50-volt supplies to each rack.

Standard fuse mountings accommodating thirty fuses were fitted at the rear of each bay and, to avoid the unnecessary use of steps in the small amount of space between the rear of the bays and the walls, the fuse mountings were fitted at a height within the reach of the average person. The mountings were modified by the removal of some of the fuse-posts which were replaced by pieces of " Micanite "; thus the five supplies of various voltages and 17 c/s ringing were accommodated on one panel without any possibility of short-circuits when fuses were replaced.

Jack mountings of the " gate " type (No. D66087) were utilised as "key and alarm lamp panels," the key mountings being fitted in lieu of jacks, and drilled to take the necessary lamp jacks.

Description.

The general layout presented many difficulties, chiefly owing to the limited amount of space available,

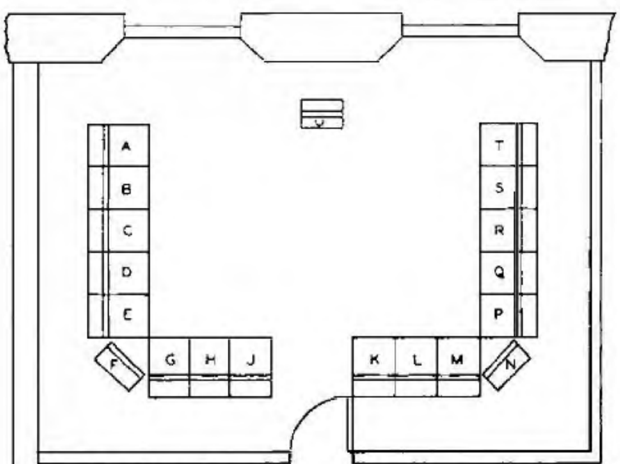

FIG. 2.—FLOOR PLAN OF INLAND TRANSMISSION ROOM. (SCALE 1 CM. = 3 FT.)

and the final arrangement (Fig. 2) permitted the maximum number of bays to be installed viz :—eighteen full-sized 10-ft. 6-in. bays and one 7-ft. bay. The two angle bays (F and N) are so positioned that only flush-mounted equipment could be used on the front of these bays; they were therefore utilised for an A.C. bridge and miscellaneous items, including a blackboard for use as a bulletin board. The rear of these bays accommodates the strip-mounted relay sets for the both-way circuits (diag. TL1584 mod.) and for the visual engaged lamps, also the 40-db. amplifier for the monitoring loudspeaker which is mounted in a directional gimbal on the side of bay U.

The total equipment installed comprises six D.C. testing bays (bays A,C,H,K,Q and S), six A.C. testing bays (bays B,D,J,L,R and T), two pairs of bays (bays E and G, M and P) equipped with direct-reading transmission measuring sets (RP125) and Ryall-Sullivan continuously variable oscillators (No. 12B) for use on music and similar higher grade circuits, two angle bays (bays F and N) mentioned above and one 7-ft. bay (bay U) equipped with 2 V.F. testing equipment.

A view of one corner of the room is shown in Fig. 3;

FIG. 3.—CORNER OF INLAND TRANSMISSION TESTING ROOM.

the bays shown are bays R-K reading from left to right. It will be noticed that the Units, Signalling No. 5 mounted above the transmission measuring sets (Testers RP 790) have been flush-mounted to avoid shadow on the meters below, and on the D.C. bays the attenuators and key and alarm lamp panels have been mounted as high as possible, consistent with ease of operation, above the voltmeters for the same reason, as this equipment cannot be flush-mounted. The monitoring unit above the direct reading transmission measuring set (Tester RP 125) does not affect the reading of the scale on the T.M.S. as this is of the mirror-galvanometer type using a reflected spot of light. In order to avoid the cord of the telephone instrument hanging down across the scale, however, the telephone jack is connected in parallel to a second jack under the writing shelf.

The test tablet below the impedance bridge gives direct access via test extensions to all points where main cables terminate in Faraday Buildings, and similarly the test tablet above the monitoring unit gives connection to all music-switching frames in Faraday Buildings. This facility is only provided on the two bays equipped with direct reading transmission measuring sets (RP 125) as measurements on higher grade circuits are made only on these sets.

All the bays with the exception of bay "U" are equipped with writing desks 1 ft. 5½ in. wide, fibre-covered and finished matt black, a feature of these desks being the pen-trays and sunken ink-wells.

A face equipment view of three typical bays is shown in Fig. 4. Reading from left to right the bays are (1) A.C. bay, (2) D.C. bay, (3) higher grade A.C. bay. It will be noticed that full jack field facilities are provided on the D.C. bays, but only a selection of the circuits appear on the smaller jack field on the higher grade A.C. bays.

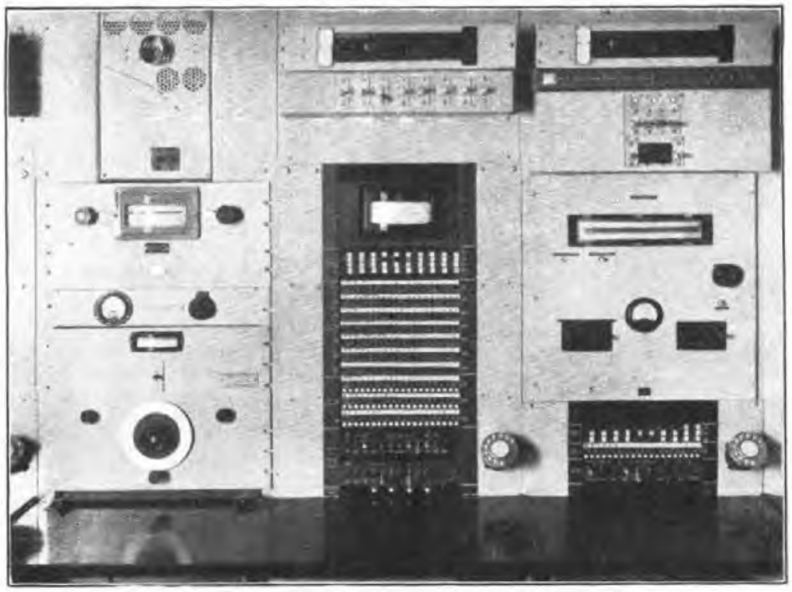

FIG. 4.—FACE EQUIPMENT OF THREE TYPICAL BAYS.

All the circuits (both telephone and test extensions) are multipled over all the large jack fields, and it will be seen that visual engaged lamps are fitted to avoid overlapping. Connections on the jack fields are made by the use of short double-ended cords to avoid the fitting of pulley weights, etc., in the limited leg space available.

Conclusion.

The new equipment has been in service since August, 1945, and has given every satisfaction. The suite was brought into use with a minimum of interruption to the steady flow of work. The layout and facilities provided have amply justified the work and time involved in their conception. The design of a number of the circuits, the layout and installation of the equipment, was carried out by the Engineering Division of the Long Distance Area.

This brief description of what is thought to be the first room designed and equipped to facilitate the efficient and speedy lining-up of inland repeatered circuits will, it is hoped, be of interest to others whose problems may be of a similar nature.

Flexibility Units for Local Line Networks

J. P. HARDING, B.Sc. (Eng.), A.M.Inst.C.E., A.M.I.E.E., and A. J. HUMPHRIES

U.D.C. 621.315.68 : 621.395.74

Part 2.—Terminal Strip Assemblies

The flexibility units described in Part I of this article require a special arrangement of terminal strip. The construction and mounting details of two types of strip designed for the purpose are given in this second and concluding part of the article.

General.

TO meet the requirements of the cross connection field discussed in Part I of this article, new forms of terminal strip have been designed in which exchange and local pairs are terminated on separate tags opposite each other on the same terminal strip. This construction allows the use of short bare wires for making the direct connection between an exchange and the corresponding local pair while retaining the facility of connecting between any exchange and any local pair by running a jumper. There is thus no restriction on the cross connection of any pair as opposed to the limitations of the auxiliary joint in which only a proportion of the pairs is available for re-distribution. Estimates, since borne out by detailed investigation of individual schemes, show that in the majority of instances fewer than 25 per cent. of the circuit capacity of an installation need at any time to be connected by jumpers. The reduction of jumpers to so low a proportion avoids congestion, permits efficient maintenance conditions and greatly minimises the occurrence of disconnections and contacts and the difficulties of tracing connections within the cabinet.

Two designs of terminal strip—an open and an enclosed type—have been produced to meet the requirements discussed. On both types the "main" cable terminations, i.e., on the "exchange" side, are wired to the left hand side of the strip marked "E," and "local" terminations, i.e., on the distribution side, to the right marked "D." Copper wire pins with coloured plastic heads are used for making the direct bridge connections. A slot in the plastic head enables the pin to be withdrawn conveniently with the blade of a screwdriver.

Open Type Strip.

The open type strip (illustrated in Fig. 1) is moulded from black bakelite B.S. 771-GX in 10+10 pair units 5¼ in. long, which may subsequently be assembled together vertically to form a unit of the necessary capacity. The dimensions of the 10+10 pair strip are the outcome of a compromise in which as many circuits as possible have been accommodated in the minimum space consistent with the use and spacing of terminals of sufficiently robust construction and the eventual assembly of strips in vertical formation to give a convenient numbering arrangement. For cabinets of the dimensions already quoted the arrangement chosen provides 50+50 circuits per vertical with obvious advantages in the identification and wiring of circuits. The restriction of the size of the unit strip avoids the high cost and increased risk of failures of moulding a strip 2-3 ft. long, and permits the uniting of various numbers of constituent strips as required for a particular purpose. Individual strips are first assembled together on a ¼ in. square mild steel rod which allows the terminal tags to be conveniently accessible for wiring, after which the assembly is mounted on a sheet steel box to give a satisfactory mechanical support for the whole. The box is also used to retain insulating compound with which the soldered terminations are finally sealed. The terminals are spaced at 15/32 in. centres vertically, main and local terminations being positioned directly opposite each other throughout as shown. A celastoid numbering strip is carried in a small recess running the length of the strip. Slots of a re-entrant section are provided at the edge of the strip at 35° to its face. Jumper wires may be led out from terminals through these slots and are thus prevented from coming into contact with the terminals of other circuits and giving rise to poor insulation. The particular shape of the slot section permits the jumper wire to be pressed into the slot and retained in position by a slight twist of the wire. 1 pair 12½ lb. jumper wire with polyvinyl chloride covering is used which is mechanically strong, easy to strip and non-hygroscopic.

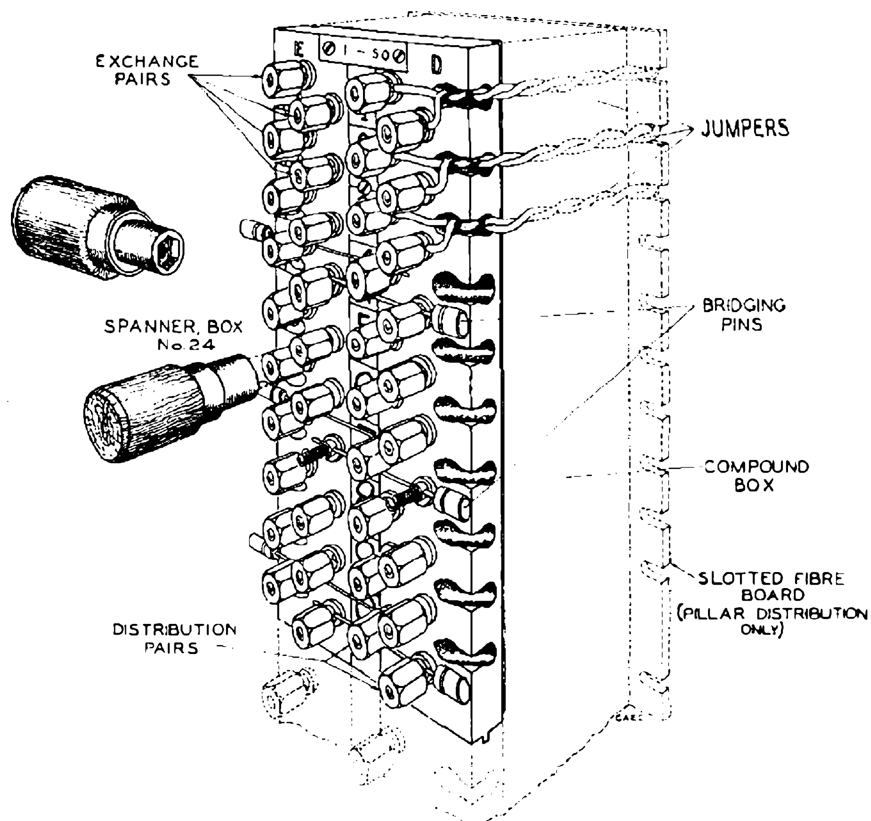

FIG. 1.—OPEN TYPE STRIP.

Considerable attention was given to the selection of the most suitable type of terminal, both for utility and ease of manufacture. So that straight bare bridge connections could be made most readily and with the least possibility of causing contact with adjacent terminals, a pillar type terminal in which the wire passes through a hole in the terminal was preferred to the ordinary screw-down connection head where no automatic alignment of the wire is provided. The ordinary type of pillar terminal was rejected on account of its small contact area and its tendency to loosen with vibration. The type finally adopted was one in which the connecting wire passes through a drilling in the stem and is secured by a hexagonal locking nut. The stem is increased in section where drilled to avoid weakness at this point. The hole in the terminal is correctly aligned in the strip by a flat on its shank. For tightening the terminal head a special box spanner shown in Fig. 1 has been devised in which the wooden handle is large enough to be convenient for use with the fingers but not so large as can be grasped in the hand and undue leverage obtained with the risk of overturning and damaging terminals.

Enclosed Type Strip.

It was realised in the early stages of design that a more compact form of terminal strip than the open type described above would be particularly valuable and allow cabinets of smaller dimensions to be employed with obvious advantages, particularly from wayleave considerations. The open type strip was already, consistent with satisfactory service, as compact as the construction permitted, and the quest for improvement beyond this standard necessarily involved some new form of connection. The strip was required, if possible, to permit the accommodation of exactly twice the number of circuits of the open type, since a smaller increase than this would have introduced difficulties in numbering. A reduction in width, compared with the open type, was also needed to allow room for an increased number of jumpers while maintaining the same lateral spacing of vertical

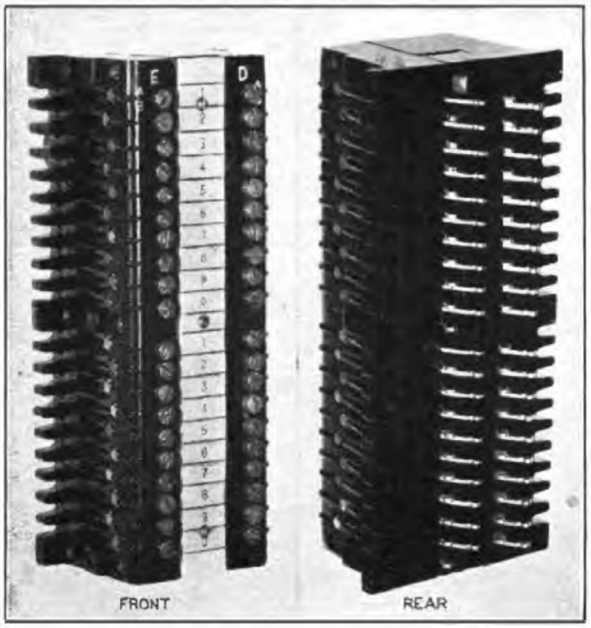

FIG. 2.—ENCLOSED TYPE STRIP.

formations. It was found possible to meet these requirements and to offer other incidental advantages in the design of the enclosed type strip shown externally in Fig. 2. This design of strip is likely to be adopted exclusively for future requirements.

The essential feature permitting the accommodation of 20 pairs in the space of 5¼ in. is the simultaneous securing of both wires of a pair through the medium of an insulated block and a single screw termed the pressure screw.

The strip is constructed in four main moulded parts —the left and right hand side members, the label block and the guide block (see Fig. 3) Both side members are fitted with twenty pressure blocks and associated contact members as later described. This form of construction enables the constituent sections (with the exception of the label block) to be moulded free of any metallic inserts, all of which are positioned and secured during the final operation of assembly. Bakelite (to B.S. 771-GX) is used for the moulding of the main members and the pressure blocks. Each side member contains a series of twenty similar rectangular cavities at the bottom of which shaped contact members are set at different levels, an intervening ridge being used to separate and insulate the contacts of a pair within each cavity. The side members which are fixed opposite each other also embody slots through which jumper wires may be passed after leaving the strip. Between the side members are secured the guide and label blocks as shown. The former (lower block) is grooved to guide bridging pins from the contact members on one side to the corresponding contact member on the opposite side.

The label block (upper block) is hollow in section and serves to close each cavity and carry the plastic face label running the length of the strip. Each cavity contains an elemental unit as shown in Fig. 3. Either bridging pins or the bared ends of jumper wires may be inserted through the holes of the side members and

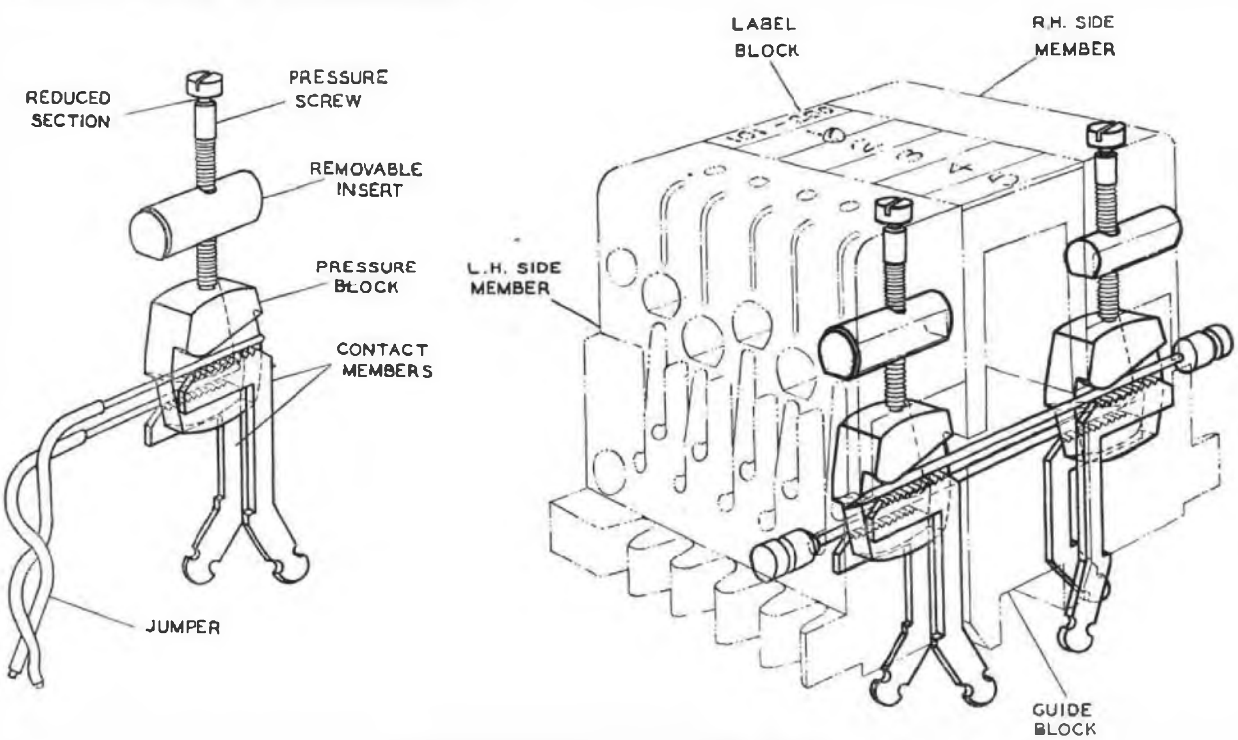

FIG. 3.—DETAILS OF ENCLOSED TYPE STRIP.

are secured between the pressure block and the contact members by the pressure screw, the reaction of which derives from the threaded loose insert in the side member. This insert is removable and may, therefore, be renewed while the strip is in service if, through abuse or otherwise, the thread becomes damaged. A niche formed in the end of the insert allows its easy withdrawal with the blade of a screwdriver. The contact members are brass stampings 48 mils. thick, shaped as shown, and formed into tags at their lower ends for soldering to the cable tails.

The curved shapes of the bearing surfaces on either side of the pressure block are complementary to each other which ensures that the two wires of a pair are secured by engagement with the contact members at two points spaced slightly apart as shown. The particular merit of this arrangement is that the pressure block, under the force of the pressure screw, will rock slightly if necessary and thus bear equally on the wires and the contact members, so providing an automatic correction for unfavourable tolerances in manufacture which might otherwise result in one wire of a pair being unduly tight, and the other insufficiently secured. An alternative design of pressure block and contact member, which has also been found particularly good in resisting the effects of vibration, is shown in Fig. 4. In this the

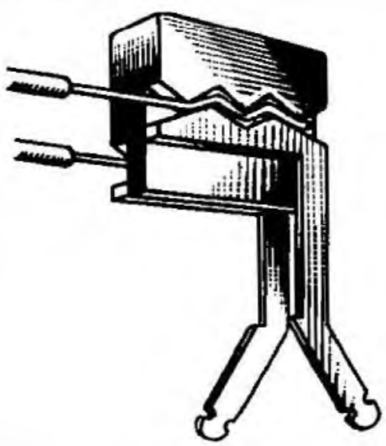

Fig. 4.—Alternative Design of Pressure Block and Contact Member.

block does not rock but the wires are secured between the large teeth formed on the block and on the contact member which engage in such a way that the wire is bent and stretched between them by a wedging action under which a high contact pressure is obtained with a moderate screw pressure. An efficient contact pressure is obtained over a considerable axial movement of the pressure screw ensuring the satisfactory connection of wires despite a possible unfavourable tolerance.

Pressure blocks of various materials, viz., bakelite, polystyrene, polyvinyl chloride and polythene have been tried. Although bakelite has been considered the most satisfactory material so far, the alternative materials mentioned possess certain advantages. Their merits lie in a lower modulus of elasticity and consequently a greater flexibility and, being capable of moulding by injection, the greater speed with which blocks can be manufactured. A disadvantage is the possible occurrence of "cold flow." The low softening point of these materials compared with bakelite also entails the risk of distortion during soldering of the tags and wax filling.

The pressure screw is reduced in section at a point immediately below its head. It is thereby caused to fail at this point if grossly overturned leaving a sufficient projection for removal with pliers.

Ribs formed on the side of the terminal strip extending from the pressure screws to the holes for receipt of wires indicate the pair applicable to each pressure screw. The electrical contact surfaces being located within the interior of the body of the strip are protected from dust and dirt and, reasonably, from the ingress of moisture. As for the open type strip, polyvinyl chloride covered jumper wire is used. In service a length ($\frac{1}{2}$ in.) is bared—sufficient to reach to the end of the contact member—the insulation being

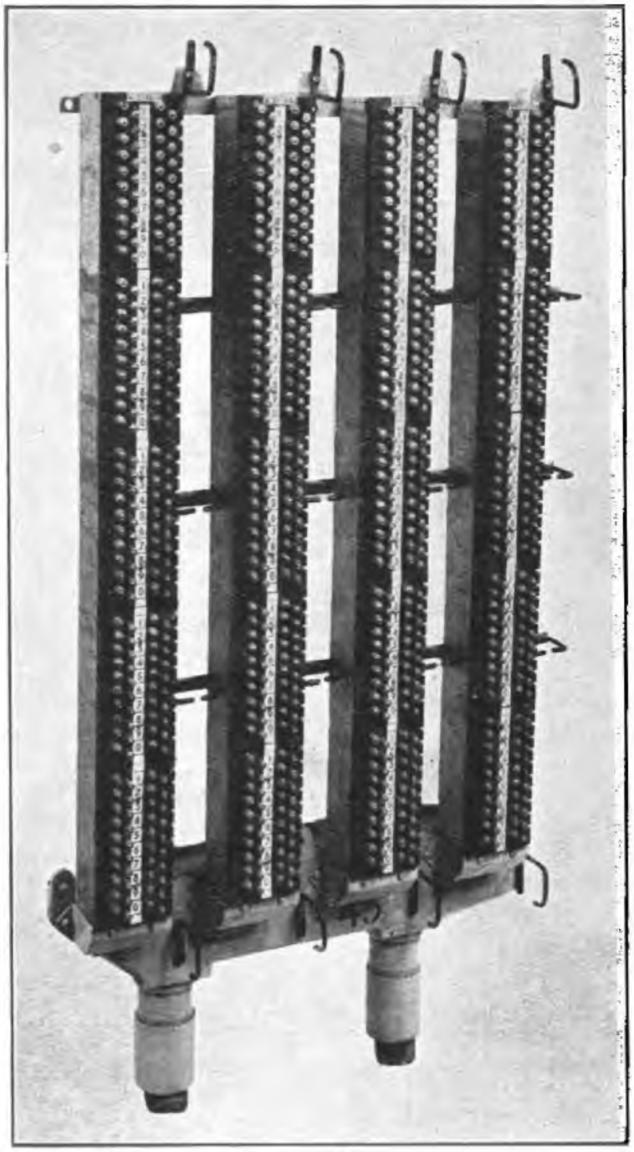

Fig. 5.—Assembly for Cross Connection Cabinet. (Incorporating Open Type Strips.)

pushed up against the hole in the side of the strip (through which it will not pass). The use of cable tails with 6½ lb. conductors instead of 10 lb. conductors used for assemblies incorporating open type strips, enables the increased number of pairs involved to be accommodated within the same size of cable gland. The strip is the subject of British Patent No. 20193/44 (A. J. Humphries).

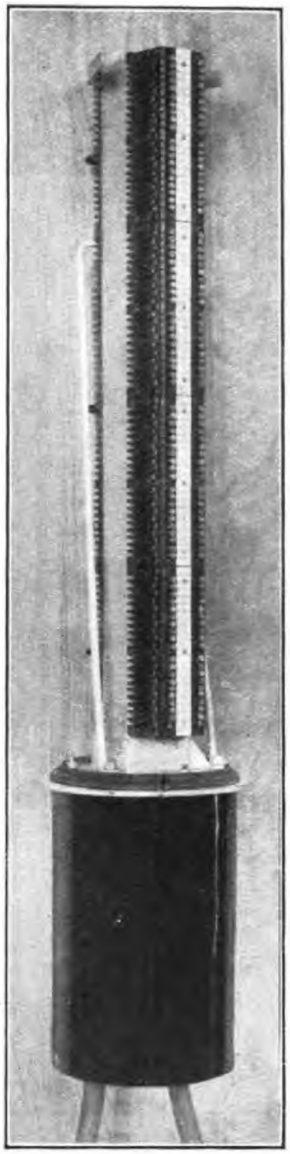

FIG. 6.—ASSEMBLY FOR PILLARS.
(Incorporating Enclosed Type Strips.)

Construction of Assemblies.

For use in cabinets, five strips of either open or enclosed type are mounted in vertical formation as described, one, two or four of such vertical formations being subsequently associated to form standard assemblies. A view of an assembly using open type strips is given in Fig. 5. To permit the maximum use of bare bridges every pair of terminals on both the "main" and "local" sides is wired out in separate exchange and distribution cable tails. These cables are, therefore, of equal capacity although the size of the exchange cable serving the cabinet will generally be less than the sum of the local distribution cable pairs. The cable tails are of paper core type and are shared between vertical formations by use of a multi-way gland to which the lead cable sheaths are plumbed and on which the vertical strip formations are supported. The laced pairs of the cables are led to the respective strips in the channels of the gland which is shaped to clear the bottom of the strips so that an unobstructed jumper field underneath them is possible. Jumper rings are fitted to the assembly as shown and are omitted from the left hand side of the first vertical. Rings for this position are mounted on a detachable steel vertical at the extreme left of the cabinet. Assemblies are issued, wired and sealed, two standard lengths of cable tails 10 ft. and 15 ft. being available for each assembly. Assemblies are fixed in cabinets by first threading through the cable tails in the appropriate conduits after which the assembly may be bolted in position.

For use in pillars, assemblies are issued as for cabinets, complete with jumper rings and exchange and distribution cable tails (see Fig. 6). The jumper rings are fixed at the rear of the strips and jumper wires pass around the back of the strip in open type rings which, in conjunction with a slotted fibre board, allows the maintenance of an orderly jumper field and leaves the front of the strip unobstructed. The arrangement of the fixing sleeve, cast gland, base and compound box is strong mechanically and rigidity of the whole is ensured by the use of twin strut supports near the centre of the assembly. The assembly is secured in the pillar base by dressing the fixing sleeve with bitumen and thrusting home until the projecting flange of the assembly bears on the top of the base.

Numbering Arrangements.

Cabinets and pillars are numbered in relation to the exchange area. Assemblies, whether for cabinets or pillars, are numbered serially in respect of each circuit. The designation of circuits is thus E 28, D 140, etc., and an instruction to set up a circuit takes the form :—"Speedwell Exchange, Cabinet No. 9, E 28—D 140" meaning that a jumper is required ; or "E 40—D 40" meaning that a direct connection by bridging pin is to be carried out. References to particular "main cable" pairs or to "D.P." pairs are intentionally avoided so that an alternative connection cannot readily be set up without the knowledge of the routing office if, through an error, the instruction a fitter receives cannot be implemented.

Acknowledgement.

Acknowledgement for valuable co-operation and advice is due to Kent Mouldings, who manufactured the first supplies of the enclosed type strip and who suggested modifications by which the strip was made suitable for quantity production.

The Reconditioning and Restoration of a Steel-Pipe Conduit Formation

C. F. THOMAS

U.D.C. 621.315.233 621.315.67

As the result of a ground subsidence a 20-way pipe-formation was left exposed, damaged, and out of alignment. The pipes deteriorated further while awaiting restoration. They were dressed with preservative coverings, re-aligned, their joints recaulked, and the formation supported on concrete piers. The spaces between pipes were packed solidly with weak cement-mortar, and left in readiness for the restoration of the subsoil and paving. The work was completed without interruption of service.

Introduction.

IN February 1943 there occurred a subsidence of the L.M.S. (Midland line) Railway embankment in the vicinity of Mill Lane Bridge (Fig. 1), on the westerly side of the line between West Hampstead and Cricklewood stations. The subsidence affected a considerable length of the bank and the western end of the bridge subsided, together with the adjoining carriageway, to a depth of about 4 feet. A cavity about 70 feet in length, and of the full width of the highway was formed, and the P.O. plant (together with a large and a small water-main) was left exposed above the final ground-level.

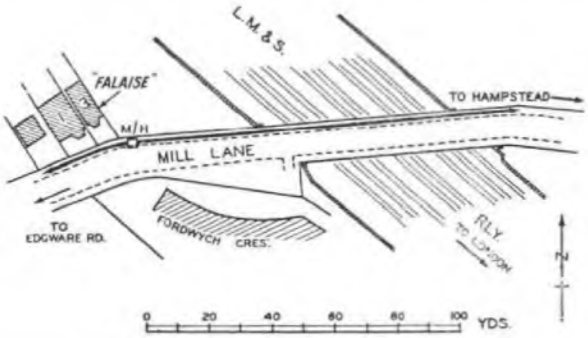

FIG. 1.—SITE OF SUBSIDENCE.

The bridge is about 60 feet above rail level, in consequence the illustrations do not show any railway plant or give any general view of the subsidence along the line. The purpose of this article is however only to describe the reconditioning of the P.O. plant and reference to railway engineering aspects of the subsidence can be limited to the observations that at midsummer 1945 the bank had been stabilised by piles driven at rail level and the sunken end of the bridge had been restored to its former level and its brickwork piers raised correspondingly.

The P.O. plant along Mill Lane consists of 18 steel and 2 cast-iron pipes under the northerly footway. Along the southerly footway a local 3-in. duct serves the house frontage "Fordwych Crescent" but terminates at the bridge; this track and its terminal jointbox also sank, but their renewal does not merit special reference.

There are six "spare" ways in the 20-way formation, and the occupied "ways" carry audio-trunk and junction cables totalling 3,300 pairs; in addition the London-Birmingham coaxial-cable and the London-Derby carrier-cables are carried. The west end of the bridge is on the boundary of the Gladstone and Hampstead exchange areas and this feature accounts for the absence of local cables in the track.

The cast-iron pipes are about 50 years old, but the steels were laid during 1925 and they are disposed on each side of a 24-inch water-main. Three of the steels cross over the water-main in the subsidence area (Fig. 2), in the course of a "folding" run for passing over the bridge at shallow cover. There is also a 5-inch water-main running among the steels across the bridge.

FIG. 2.—VIEW LOOKING EAST AS AT MIDSUMMER, 1945.

Preliminary Work.

Shortly after the initial subsidence the Metropolitan Water Board replaced its exposed cast-iron 24-inch main by a steel one, with expansion-joints; they also recovered the 5-inch main and capped off its ends. The P.O. pipes were supported temporarily by timber packing and by slinging. Progressive sinkage of the ground necessitated periodical readjustment of the timber-packings and slings; for these operations whym-screws were set on the cross-members and the pipes were hoisted and re-slung as required.

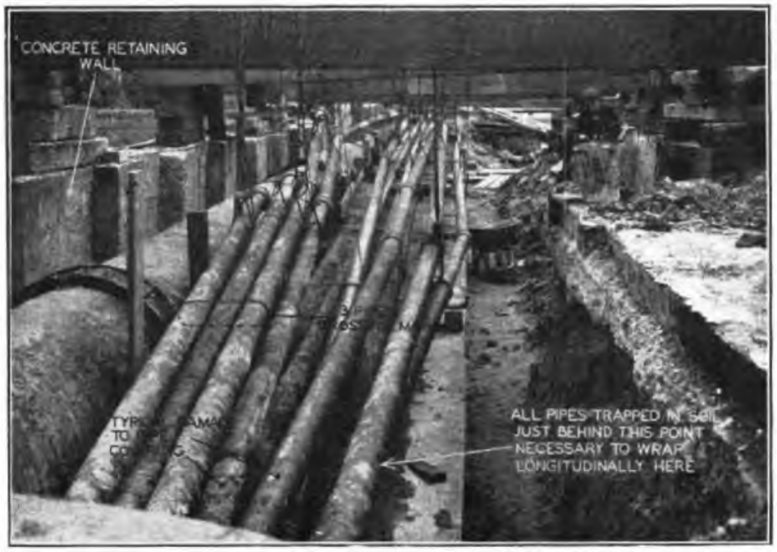

FIG. 3.—VIEW LOOKING EAST SHOWING RETAINING WALL.

The Metropolitan Water Board was the first authority to commence restoration of its plant. A concrete raft was formed beneath the main and upon this concrete piers were placed, carrying the main, after which the temporary timberwork was recovered.

The railway company's contractor next built the concrete retaining-wall shown in the left-hand side of Fig. 3 and then constructed piers below the P.O. conduit-formation. The tops of these piers were set about 9 in. below the proposed bed-line of the P.O. pipes so as to permit of final adjustment by brickwork courses built up to exact required levels. Access to site was given to the P.O. contractors at the end of July 1945. The full length of track then exposed was about 90 feet.

Reconditioning the Pipes.

As already stated the steel pipes had been under the ground for about 18 years, prior to their exposure to the weather for the two-year period following the subsidence. They had also been roughly handled in the course of the working operations of all authorities and it was scarcely surprising that about 50 per cent. of the impregnated-jute wrappings had either disappeared or hung in tatters. There was no question as to the need for reconditioning the pipes before they were again buried in the soil and approval was given to a local proposal for treating the pipes with the "paste" and "bandage" selected from the range of pipe-protection materials marketed under the trade-name "Denso."

In preparing the plant for treatment all particles of loose rust and adhering fragments of the original pipe-wrappings were removed by scraping and wire-brushing, and the pipe surfaces were then dressed with paste rubbed well in by hand and worked over the metal so that no parts escaped treatment. The purpose of the paste is to seal off the residual oxidation and to prevent further spread of oxidation by the action of air trapped under the bandage.

The bandage material is available in a range of widths and the 4 in. width was selected for use wherever spiral application might be possible. For the end sections where access was expected to be so difficult as to allow of longitudinal application only, a supply of 12 in. bandage was ordered; this offered a reasonable overlap, the pipes being 11 inches in circumference. The stock lengths of the rolls of bandage, in all widths, is 30 ft.

The natural limpness of the bandage is advantageous when applying it to irregular surfaces or covering-in projections, and no difficulty was experienced, when wrapping the steel-pipe sockets, in maintaining continuity of the wrappings.

As a precaution against abrasion of the undersides of the wrapped surfaces of the pipes by contact with hardcore, pebbles or the like it was decided to place steel-plate protection beneath them. The steel-plate decking also served the equally important purpose of providing a firm bottom on which the weak sand-cement mortar packing between pipes could be bedded. The probability of the subsidence cavity being made good with large hardcore having a substantial void-content into which the sand filling between the pipes might gravitate in course of time also influenced the decision to employ the steel plates.

The pipes having been installed in 1925 were of the lead-caulked-socket type, now obsolete in P.O. work, and it was therefore necessary to recaulk them, as the work proceeded, using lead-wool; about 90-100 joints were recaulked in the course of restoration. The two cast-iron pipes in the formation were in very fair condition although about 50 years old and as

FIG. 4.—P.O. PIPE UNDER TREATMENT.

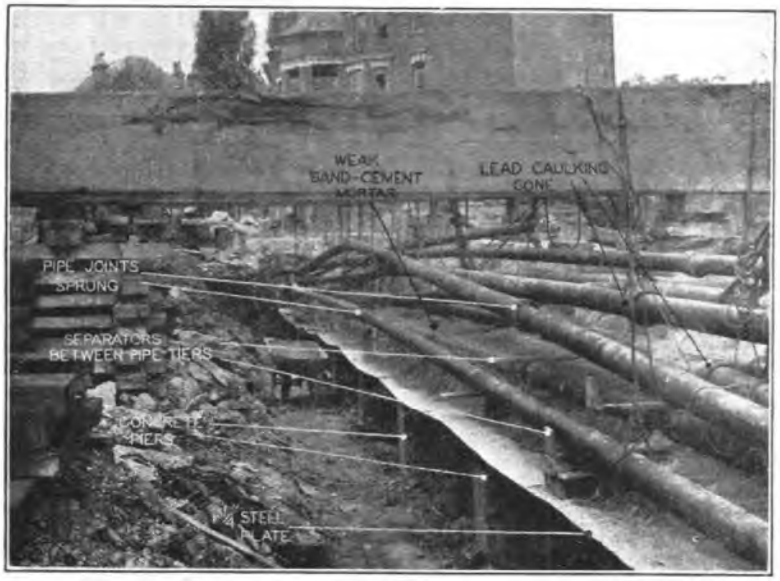

FIG. 5.—RECONDITIONING OF PIPES AT ADVANCED STAGE.

these were accessible they were cleaned and coated with "Compound No. 6" instead of being wrapped.

In Fig. 4 is shown a pipe under treatment. The portion of pipe to the left of the photo has been dressed with paste, and the bandage has been applied spirally from left to right, commencing at a point (shown by dotted line) about two feet from the left-hand side of the socket. Some impression may be gained as to the ease with which the socket projection has been covered-in. The spiral turns of bandage are shown clearly on the right-hand side, having about one inch overlap between turns.

Final Restoration.

As the pipes were restored, tier-by-tier, the interstices between them were filled solidly with weak sand-cement mortar.

At the ends of the subsidence cavity the 12 in. bandage was placed in position longitudinally, and lapped over the ends of the existing wrappings. To minimise the risk of the 12-inch wrapping becoming displaced before, or during, the filling-in operations a strip of 4-inch bandage was placed longitudinally over the seam. Fig. 5 illustrates the work at a fairly advanced stage.

All except three pipes were covered in with sand-cement mortar, and arrangements were made for covering the three pipes, which were outside the main formation, with sand at the filling-in stage. A considerable time elapsed between the completion of the P.O. work and the filling-in of the ground and re-paving of the highway, and these exposed pipes were therefore kept under observation for signs of damage to the wrappings.

Fig. 6 shows the nature of the hardcore filling eventually used, viz: brick-rubble, and it will be evident that the fears as to abrasion of the pipe wrappings and of gravitation of the fine filling material in between the pipes were not groundless.

The restoration of the pipe-formation was completed at the end of September 1945. The work was carried out by Messrs. O. C. Summers, P.O. Contractors, and supervised by Mr. H. Heal.

There was not a single cable-fault in the course of handling the pipes, if a single wire-disconnection on one of the old Birmingham cables is excepted, but this occurred in a jointing chamber at some distance east of the bridge, and may have been unconnected with the work.

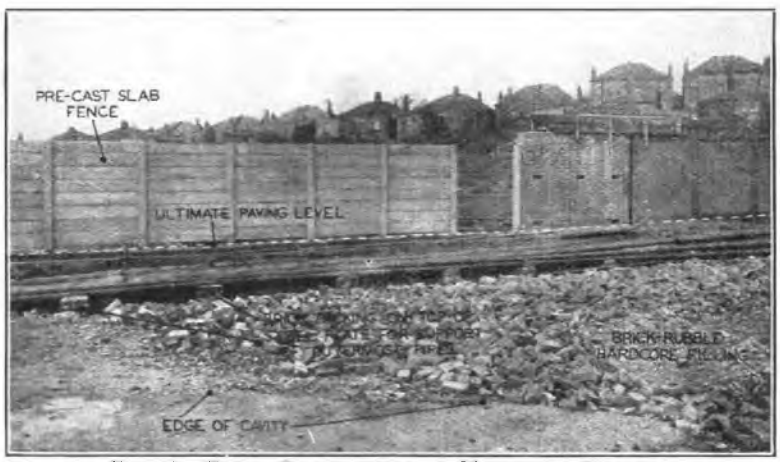

FIG. 6.—FINAL STAGE SHOWING HARDCORE FILLING.

Insertion Loss and Insertion Phase Shift of Multi-Section Zobel Filters with Equal Image Impedances

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The author shows how a previously published method of calculating the insertion loss and phase shift of lattice type filters may be applied to similar computations regarding Zobel multi-section ladder type filters with equal image impedances.

Introduction.

In a previous article[1] H. Stanesby, E. R. Broad and R. L. Corke described a method of computing the insertion loss and insertion phase shift of lattice type filters which are inserted between resistances. The loss and the phase shift are obtained in terms of the reactance values of the series and lattice arms of the lattice networks at various frequencies. The present article deals with the application of the same method of computation to multi-section ladder type filters, designed according to Zobel's theory, provided these filters possess equal image impedances at their input and output terminals (structural symmetry is not required).

Messrs. Stanesby, Broad and Corke use for their computations two charts (or a special slide rule based on these charts) which are calibrated in values of X_x/R_t and X_y/R_t, where X_x and X_y are the reactances of the series and lattice arms, respectively, and R_t is the resistance of the source and the load. The charts give directly the loss and the phase shift as functions of X_x/R_t and X_y/R_t.

This method can, at least in principle, be applied to any given filter network which possesses a lattice equivalent, by deriving this equivalent from the given network and computing the loss and the phase shift of the equivalent network which are equal to those of the original network. It is known that any network which is structurally symmetrical possesses a lattice equivalent which can be derived without much difficulty by Bartlett's bisection theorem.[2] However, structural symmetry, though a sufficient, is not a necessary condition for the existence of a lattice equivalent. If a network possesses electrical symmetry, i.e., if its two image impedances are equal, a lattice equivalent always exists whether or not the network has a symmetrical structure.

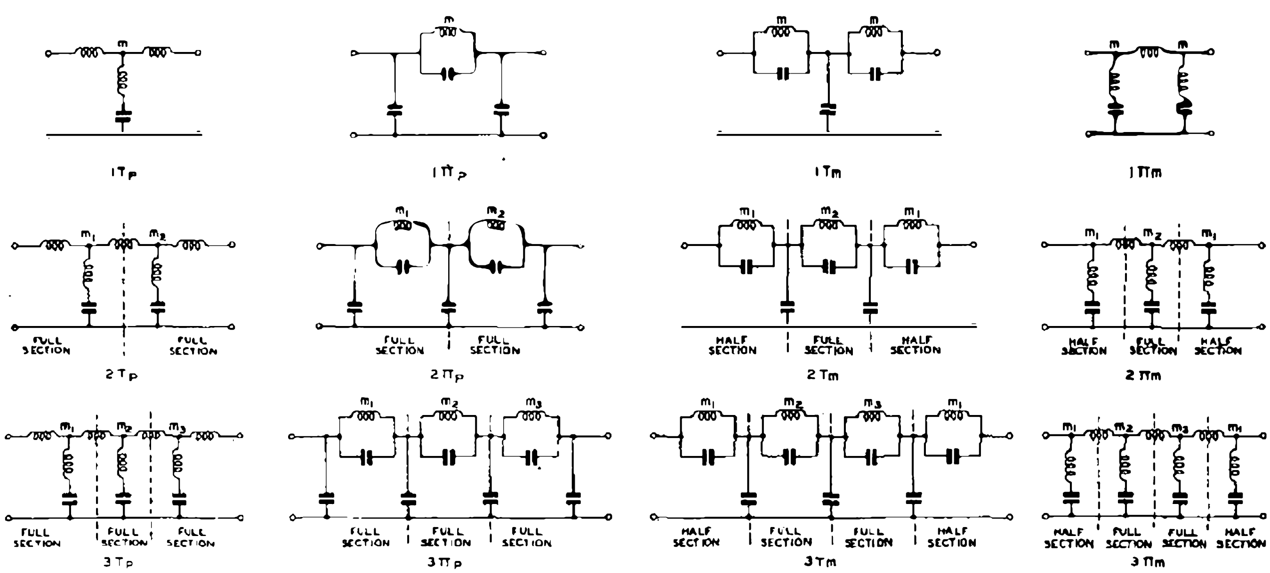


FIG. 1.—FILTER TYPES CONSIDERED, INDICATING CODING SYSTEM.

The latter case, electrical without structural symmetry, occurs frequently in multi-section filters but, since Bartlett's theorem cannot be applied, the derivation of the lattice equivalents is usually rather tedious. This may act as a deterrent in everyday engineering practice to the application of the Stanesby, Broad and Corke method to networks to which it could be applied in principle. To encourage and simplify this application as far as multi-section Zobel filters with equal image impedances are concerned, the writer of this article has derived the reactance/frequency functions of a great number of such filters, and the results are given in an easily usable, tabulated form.

[1] *P.O.E.E.J.*, Vol. 35, pp. 88 and 111.

[2] *Philosophical Magazine*, Vol. 4, p. 902, November, 1927.

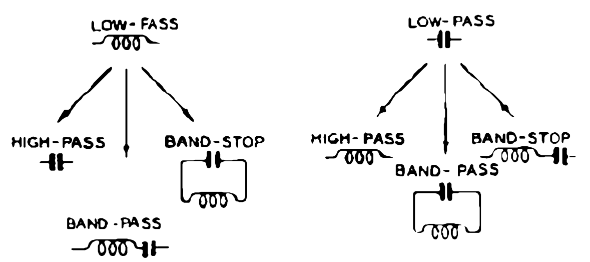
Types of Filter Considered.

In ordinary filter practice, which is usually based on Zobel's work, composite filter networks consist of a number of full and half sections which at their junctions have equal image impedances. The types of sections which are used most frequently are constant-K or prototype sections, and m-derived sections. To obtain equal image impedances at the input and output terminals of a composite filter—the condition necessary for the existence of an equivalent lattice structure—half-sections can be used in pairs only, either connected to one full-section or as two end half-sections, with equal m-values.

It is well known that high-pass, band-pass and band-stop filters can be obtained from low-pass filters by certain simple network transformations as shown in Table 1, and the performance characteristics of the resulting filters can also be obtained from those of the original low-pass filters by certain corresponding frequency transformations which are given in the top part of Table 2.[3] In view of these relations it seems sufficient to discuss the lattice equivalents of low-pass filters.

TABLE 1.

The Low-Pass Filter Types shown in Fig. 1 can be transformed into corresponding High-Pass, Band-Pass and Band-Stop Filter Types by transforming the Network Elements as shown below.



The filter types discussed in this article are shown in Fig. 1. There are four one-section filters, four two-section filters and four three-section filters. The dotted lines indicate the full and half-sections of which the multi-section filters are composed. To designate these filters a coding system has been used which deviates in some respects from Zobel's nomenclature but which, it is hoped, is more convenient from the point of view of practical application. In this coding system one number and two letters are used. The number indicates the number of full sections, including pairs of half-sections. The first letter is either a "T" or a "π" and indicates whether the filter ends in two series arms, like a T-section, or in two shunt arms, like a π-section. The second letter is a "p" or an "m" and indicates whether the image impedances at the input and output terminals of the network have the character of prototype (or constant-K) image impedances, or of m-derived image impedances.[4]

The Stanesby, Broad and Corke method is not restricted to filters whose nominal impedance R_o is equal to the load and source resistance R_t. Therefore, no such restriction applies to the filters discussed in this article.

The Reactance Functions of the Lattice Equivalents.

Each of the filters given in Fig. 1 is characterised, apart from its structure, which is given by the circuit diagram or the code designation, by the following values: its nominal or zero frequency image impedance R_o, its cut-off frequency f_o, and by a number of m-values which refer to the individual sections. In multi-section filters in the designations of which the second letter is an "m" the symbol "m_1" always refers to the two end half-sections.

As already mentioned, the equivalent lattice net-

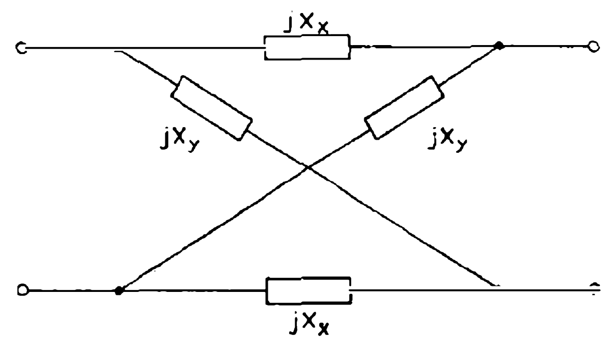


FIG. 2.

works consist of two arms with reactances X_x and two arms with reactances X_y (see Fig. 2). For the application of the Stanesby, Broad and Corke method it is not necessary to know the structure and the element values of these arms. It is sufficient to know the reactances as functions of the frequency f. These functions are given in Table 2 for each of the 12 filter types shown in Fig. 1.[5] They contain as parameters the values of R_t, R_o, f_o and the various m-values (or the corresponding a-values). Since, however, R_t and R_o always appear in the combination R_o/R_t and f_o always together with f in the combination f/f_o, it is convenient to introduce the new symbols

$$r = R_o/R_t$$
$$\text{and } x = f/f_o.$$

and to give the required expressions for X_x/R_t and X_y/R_t as functions of x with the value of r and the various m's as parameters. In this way the number of parameters is decreased by two for all practical purposes.

If in Table 2 the expression for X_x/R_t referring to any filter type is multiplied with the expression

[3] The performance curves, as functions of frequency, of the band-pass and band-stop filters thus obtained are symmetrical about their mid-band frequency when a logarithmic frequency scale is employed. There are also band-pass sections in practical use which do not possess this kind of frequency symmetry; however, filters containing such sections are beyond the scope of the present article.

[4] It is shown in classical filter theory that an m-derived half-section has two different image impedances, a prototype image impedance at one side and a modified impedance, depending on the value of m, at the other side.

[5] The derivation of these formulæ is given later.

TABLE 2

Filter Design Parameters

R_t = Resistance of source and load.
R_0 = nominal image impedance.
$r = \frac{R_0}{R_t}$
f_0, f_1, f_2 = cut-off frequencies.
m, m_1, m_2, m_3 = m-values of sections (see Fig. 1).
$a^2 = 1/(1 - m^2)$, $a_1^2 = 1/(1 - m_1^2)$

Independent Variable

$x = \frac{f}{f_0}$ for low-pass filter.
$x = \frac{f_0}{f}$ for high-pass filter.
$x = \frac{f - f_1 f_2/f}{f_2 - f_1}$ for band-pass filter.
$x = \frac{f_2 - f_1}{f - f_1 f_2/f}$ for band-stop filter.

where f = frequency.

Type of Filter	X_x/R_t	X_y/R_t
1 T p	$+ r\, mx$	$+ \frac{r}{m} \frac{x^2 - 1}{x}$
1 π p	$- r m \frac{x}{x^2 - 1}$	$- \frac{r}{m} \frac{1}{x}$
1 T m	$- r\, a^2 m \frac{x}{x^2 - a^2}$	$- r \frac{a^2}{m} \frac{x^2 - 1}{x(x^2 - a^2)}$
1 π m	$+ r \frac{m}{a^2} \frac{x\,(x^2 - a^2)}{x^2 - 1}$	$+ r \frac{1}{a^2 m} \frac{x^2 - a^2}{x}$
2 T p	$+ r \frac{m_1 + m_2}{1 + m_1 m_2} \frac{x\,(x^2 - 1)}{x^2 - 1/(1 + m_1 m_2)}$	$+ r \frac{1 + m_1 m_2}{m_1 + m_2} \frac{x^2 - 1/(1 + m_1 m_2)}{x}$
2 π p	$- r \frac{m_1 + m_2}{1 + m_1 m_2} \frac{x}{x^2 - 1/(1 + m_1 m_2)}$	$- r \frac{1 + m_1 m_2}{m_1 + m_2} \frac{x^2 - 1/(1 + m_1 m_2)}{x\,(x^2 - 1)}$
2 T m	$- r a_1^2 \frac{m_1 + m_2}{1 + m_1 m_2} \frac{x\,(x^2 - 1)}{(x^2 - a_1^2)\left(x^2 - 1/(1 + m_1 m_2)\right)}$	$- r a_1^2 \frac{1 + m_1 m_2}{m_1 + m_2} \frac{x^2 - 1/(1 + m_1 m_2)}{x\,(x^2 - a_1^2)}$
2 π m	$+ \frac{r}{a_1^2} \frac{m_1 + m_2}{1 + m_1 m_2} \frac{x\,(x^2 - a_1^2)}{x^2 - 1/(1 + m_1 m_2)}$	$+ r \frac{1}{a_1^2} \frac{1 + m_1 m_2}{m_1 + m_2} \frac{(x^2 - a_1^2)\left(x^2 - 1/(1 + m_1 m_2)\right)}{x\,(x^2 - 1)}$
3 T p	$+ rH \frac{x\,(x^2 - b^2)}{x^2 - c^2}$	$+ r \frac{1}{H} \frac{(x^2 - 1)\,(x^2 - c^2)}{x\,(x^2 - b^2)}$
3 π p	$- rH \frac{x\,(x^2 - b^2)}{(x^2 - 1)\,(x^2 - c^2)}$	$r \frac{1}{H} \frac{x^2 - c^2}{x(x^2 - b^2)}$
3 T m	$- r a_1^2 H \frac{x\,(x^2 - b^2)}{(x^2 - a_1^2)\,(x^2 - c^2)}$	$- r \frac{a_1^2}{H} \frac{(x^2 - c^2)\,(x^2 - 1)}{x(x^2 - a_1^2)\,(x^2 - b^2)}$
3 π m	$+ \frac{rH}{a_1^2} \frac{x\,(x^2 - a_1^2)\,(x^2 - b^2)}{(x^2 - c^2)\,(x^2 - 1)}$	$+ r \frac{1}{a_1^2 H} \frac{(x^2 - a_1^2)\,(x^2 - c^2)}{x\,(x^2 - b^2)}$

$$H = \frac{m_1 + m_2 + m_3 + m_1 m_2 m_3}{1 + m_1 m_2 + m_2 m_3 + m_3 m_1} \; ; \; b^2 = \frac{m_1 + m_2 + m_3}{m_1 + m_2 + m_3 + m_1 m_2 m_3} \; ; \; c^2 = \frac{1}{1 + m_1 m_2 + m_2 m_3 + m_3 m_1}$$

for X_y/R_t referring to that filter type which can be obtained from the first type by replacing in its code designation " T " by " π," or vice versa, the product is always $-(R_0/R_t)^2$.

A Practical Example.

As an example of the practical application of Table 2, a low-pass filter consisting of three prototype

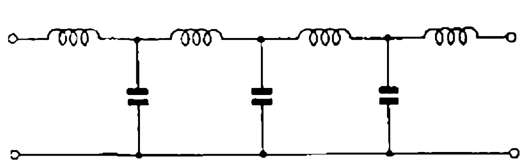
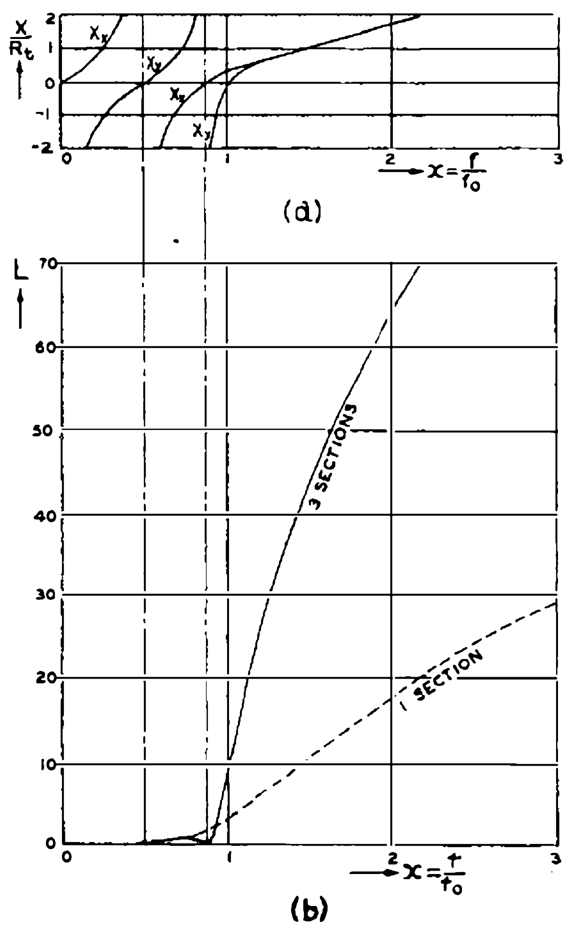


FIG. 3.—LOW-PASS FILTER CONSISTING OF 3-PROTOTYPE SECTIONS.

sections, as shown in Fig. **3**, will be discussed. By comparing this filter with the networks in Fig. **1** it is found that the designation for the filter to be investigated is 3Tp with the m-values $m_1 = m_2 = m_3 = 1$. It will be assumed that the resistances R_t of the source and the load, between which the filter is to be inserted, are equal to the nominal image impedance R_o of the filter, so that $r = 1$. Then the formulæ for X_x/R_t and X_y/R_t become

$$\frac{X_x}{R_t} = x\,\frac{x^2 - \frac{3}{4}}{x^2 - \frac{1}{4}} \text{ and } \frac{X_y}{R_t} = \frac{(x^2 - 1)\,(x^2 - \frac{1}{4})}{x\,(x^2 - \frac{3}{4})} \quad (1)$$

These functions are plotted as functions of x in



(*a*) Reactance Curves for Lattice Equivalent of Filter in Fig. 3.

(*b*) Insertion Loss (db.) of Filter in Fig. 3.

Fig. 4

Fig. **4**(*a*). The resulting insertion loss L is plotted in Fig. **4**(*b*). The values for this curve were obtained with the special slide rule for insertion loss computations mentioned above, with the exception of the highest L-values for which it was necessary to use the formula given in the article by Stanesby, Broad and Corke,

$$L = 20 \log_{10} \operatorname{cosec} (\phi - \theta) \quad \ldots\ldots\ldots\ldots\ldots (2)$$

where

$$\tan\theta = \frac{X_x}{R_t} \text{ and } \tan\phi = \frac{X_y}{R_t} \quad \ldots\ldots\ldots\ldots\ldots (3)$$

For comparison purposes Fig. **4**(*b*) also shows the insertion loss of a single prototype section which is given by the well-known expression

$$L = 10 \log_{10} (1 + x^6).$$

It can be seen that the insertion loss curve of the three-section filter is not simply a magnification of the loss curve of the single-section filter, but has a different shape.[6]

For numerical computation of a loss curve the method described above is quite convenient. For a general discussion of the shape of a loss curve, however, it is better to derive its analytic expression instead of stopping the analytic work when the expressions for X_x/R_t and X_y/R_t are obtained. An analytic expression for the loss of the three-section filter can easily be obtained by means of the relation

$$L = 10 \log_{10}\left[1 + \left(\frac{1 + \frac{X_x}{R_t}\cdot\frac{X_y}{R_t}}{\frac{X_x}{R_t} - \frac{X_y}{R_t}}\right)^2\right] \quad ..(4)$$

which can be derived from (2) and (3) by writing $\operatorname{cosec}^2 (\phi - \theta)$ in the form

$$1 + \frac{1}{\tan^2(\phi - \theta)} = 1 + \left(\frac{1 + \tan\phi\tan\theta}{\tan\phi - \tan\theta}\right)^2$$

Combining equations (1) and (4)

$$L = 10 \log_{10}\left[1 + 256\,x^6\,(x^2 - \tfrac{1}{4})^2\,(x^2 - \tfrac{3}{4})^2\right] \quad ..(5)$$

It can be seen that

$$L = 0 \text{ for } x = \tfrac{1}{2} \text{ and for } x = \sqrt{\tfrac{3}{4}}.$$

By differentiation it can be shown that L has two maxima, at $x = 0{\cdot}374$ and at $x = 0{\cdot}758$, and that the respective L-values are 0·014 db. and 0·635 db. A further numerical investigation confirms that (5) agrees with the curve plotted in Fig. **4**(*b*).

A general investigation and discussion of analytic expressions for the loss and phase shift curves of the filter networks discussed here is being carried out at present.

Derivation of the Formulæ for X_x and X_y in Table 2.

For a lattice network consisting of two series arms with impedance Z_x and two lattice arms with impedance Z_y the following relations hold:

$$Z_x = Z_o \tanh\frac{\theta}{2} \text{ and } Z_y = \frac{Z_o}{\tanh\frac{\theta}{2}} \quad \ldots\ldots\ldots (6)$$

where θ is the image transfer constant of the network and Z_o is its image impedance (see Starr, "Electric Circuits and Wave Filters," 2nd ed., p. 368). Since the impedances Z_x and Z_y are purely reactive,

$$Z_x = jX_x \text{ and } Z_y = jX_y \quad \ldots\ldots\ldots\ldots\ldots\ldots (7)$$

where X_x and X_y are the reactances of the network arms. Combining equations (6) and equations (7)

$$X_x = -jZ_o \tanh\frac{\theta}{2} \text{ and } X_y = -jZ_o/\tanh\frac{\theta}{2} \quad ..(8)$$

[6] It should be emphasised that in neither of these curves is the effect of dissipation taken into account.

Thus, to find X_x and X_y it is necessary to find Z_o and $\tanh \theta/2$.

Z_o depends on the type of termination but not on the number of sections. In the above-mentioned book by Starr, on p. 243, the formulæ for Z_o are given, from which the following expressions can be derived :

Type of Termination	Tp	πp	Tm	πm
Z_o/R_t	$r\sqrt{(1-x^2)}$	$r/\sqrt{(1-x^2)}$	$ra^2 \frac{\sqrt{(1-x^2)}}{a^2-x^2}$	$\frac{r}{a^2} \frac{a^2-x^2}{\sqrt{(1-x^2)}}$

In the same book the expression for the image transfer constant of one full section is given on p. 243 as

$$\sinh(\theta/2) = jmx/\sqrt{(1 - x^2/a^2)} \qquad (9)$$

This may be rewritten in the form

$$\tanh(\theta/2) = mx/\sqrt{(x^2 - 1)} \qquad (10)$$

Equation (10) has the advantage that the parameter m occurs only once and not, as in equation (9) twice as m itself and in the form of a^2). Thus for one section:

$$\tanh(\theta/2) = mx/\sqrt{(x^2 - 1)}$$

for two sections :

$$\tanh\left[\tfrac{1}{2}(\theta_1+\theta_2)\right] = \frac{m_1+m_2}{1+m_1m_2} \cdot \frac{x\sqrt{(x^2-1)}}{x^2-1/(1+m_1 m_2)}$$

and for three sections :

$$\tanh\left[\tfrac{1}{2}(\theta_1+\theta_2+\theta_3)\right] = H\frac{x(x^2-b^2)}{\sqrt{(x^2-1)}\,(x^2-c^2)}$$

where

$$H = \frac{m_1+m_2+m_3+m_1m_2m_3}{1+m_1m_2+m_2m_3+m_3m_1}$$

$$b^2 = \frac{m_1+m_2+m_3}{m_1+m_2+m_3+m_1m_2m_3}$$

$$c^2 = \frac{1}{1+m_1m_2+m_2m_3+m_3m_1}$$

If the expressions given above for Z_o and $\tanh\theta/2$ are substituted in equations (8), the expressions for X_x/R_t and X_y/R_t given in Table 2 are obtained by multiplication or division, respectively. The signs of X_x/R_t and X_y/R_t have to be chosen so that the expressions given represent physical reactance networks.

Multi-Section Filters.

Table 2 gives expressions of X_x/R_t and X_y/R_t for one-, two- and three-section filters. It is easy to derive expressions of a similar form also for four- and five-section filters. The derivation follows closely that described above for one-, two- and three-sections. The expressions shown in Table 3 are obtained.

It can easily be seen that the general form of X_x/R_t and X_y/R_t—excepting the meaning of F(x)—for the four-section filter remains the same for any filter consisting of an even number of sections, and similarly the general form of X_x/R_t and X_y/R_t given for the five-section filter is valid for any filter consisting of an odd number of sections. However, the expressions for F(x) increase in complexity with the number of sections.

It is convenient to have F(x) in a form in which its zeros and poles are clearly recognisable since they become resonant and anti-resonant frequencies of X_x, or anti-resonant and resonant frequencies of X_y. For more than five sections it is not possible to derive simple algebraic expressions for these zeros and poles, but a general formula (for n-section filters) for F(x) can be given in the following form (based on the fact that $F(x) = (x^2-1)^{\pm\frac{1}{2}} \tanh\frac{\theta}{2}$).

n even : $$F(x) = H x \frac{(x^2-x_2^2)(x^2-x_4^2)\dots(x^2-x_{n-2}^2)}{(x^2-x_1^2)(x^2-x_3^2)\dots(x^2-x_{n-1}^2)}$$

TABLE 3

	X_x/R_T	X_y/R_T	
4Tp	$+\,r(x^2-1)\,F(x)$	$+\,\frac{r}{F(x)}$	$Fx = Hx\frac{x^2-b^2}{(x_2-d^2)(x^2-g^2)}$
4πp	$-\,r\,F(x)$	$-\,\frac{r}{(x^2-1)\,F(x)}$	$b^2 = \frac{S_1}{S_1+S_3}$; $\frac{d^2}{g^2} = \frac{1+\frac{1}{2}S_2}{1+S_2+S_4} \pm \sqrt{\left(\frac{1+\frac{1}{2}S_2}{1+S_2+S_4}\right)^2 - \frac{1}{1+S_2+S_4}}$
4Tm	$-\,\frac{ra_1^2(x^2-1)\,F(x)}{x^2-a_1^2}$	$-\,\frac{ra_1^2}{(x^2-a_1^2)\,F(x)}$	$H = \frac{S_1+S_3}{1+S_2+S_4} = \tanh(\psi_1+\psi_2+\psi_3+\psi_4)$ where $\psi_1 = \tanh^{-1}m_1, \dots\dots \psi_4 = \tanh^{-1}m_4$
4πm	$+\,\frac{r(x^2-a_1^2)\,F(x)}{a_1^2}$	$+\,\frac{r(x^2-a_1^2)}{a_1^2(x^2-1)\,F(x)}$	$S_1 = m_1+m_2+m_3+m_4$, $S_2 = m_1m_2+m_1m_3+m_1m_4+m_2m_3+m_2m_4+m_3m_4$ $S_3 = m_1m_2m_3+m_1m_2m_4+m_1m_3m_4+m_2m_3m_4$, $S_4 = m_1m_2m_3m_4$
5Tp	$+\,r\,F(x)$	$+\,\frac{r(x^2-1)}{F(x)}$	$Fx = Hx\frac{(x^2-b^2)(x^2-c^2)}{(x^2-d^2)(x^2-g^2)}$
5πp	$-\,\frac{r\,F(x)}{x^2-1}$	$-\,\frac{r}{F(x)}$	$\frac{b^2}{c^2} = \frac{S_1+\frac{1}{2}S_3}{S_1+S_3+S_5} \pm \sqrt{\left(\frac{S_1+\frac{1}{2}S_3}{S_1+S_3+S_5}\right)^2 - \frac{S_1}{S_1+S_3+S_5}}$; $\frac{d^2}{g^2} = \frac{1+\frac{1}{2}S_2}{1+S_2+S_4} \pm \sqrt{\left(\frac{1+\frac{1}{2}S_2}{1+S_2+S_4}\right)^2 - \frac{1}{1+S_2+S_4}}$
5Tm	$-\,\frac{ra_1^2\,F(x)}{x^2-a_1^2}$	$-\,\frac{ra_1^2(x^2-1)}{(x^2-a_1^2)\,F(x)}$	$H = \frac{S_1+S_3+S_5}{1+S_2+S_4} = \tanh(\psi_1+\psi_2+\psi_3+\psi_4+\psi_5)$ where $\psi_1 = \tanh^{-1}m_1 \dots\dots \psi_5 = \tanh^{-1}m_5$ $S_1 = m_1+m_2+m_3+m_4+m_5$, $S_2 = m_1m_2+m_1m_3+m_1m_4+m_1m_5+m_2m_3+m_2m_4+m_2m_5+m_3m_4+m_3m_5+m_4m_5$
5πm	$+\,\frac{r(x^2-a_1^2)\,F(x)}{a_1^2(x^2-1)}$	$+\,\frac{r(x^2-a_1^2)}{a_1^2\,F(x)}$	$S_3 = m_1m_2m_3+m_1m_2m_4+m_1m_2m_5+m_1m_3m_4+m_1m_3m_5+m_1m_4m_5+m_2m_3m_4+m_2m_3m_5+m_2m_4m_5+m_3m_4m_5$ $S_4 = m_1m_2m_3m_4-m_1m_2m_3m_5+m_1m_2m_4m_5+m_1m_3m_4m_5+m_2m_3m_4m_5$, $S_5 = m_1m_2m_3m_4m_5$

n odd: $$F(x) = Hx \frac{(x^2 - x_2^2)(x^2 - x_4^2)\ldots\ldots(x^2 - x_{n-1}^2)}{(x^2 - x_1^2)(x^2 - x_3^2)\ldots\ldots(x^2 - x_{n-2}^2)}$$

where $H = \tanh(\psi_1 + \psi_2 + \psi_3 + \ldots\ldots + \psi_n)$;

$\psi_1 = \tanh^{-1} m_1, \ldots \psi_n = \tanh^{-1} m_n$.

$x_1 < x_2 < \ldots\ldots < x_{n-1} < 1$;

$x_1, x_3, x_5, \ldots\ldots$ are the values of x at which the image phase shift coefficient of the filter has the values $\pi, 3\pi, 5\pi, \ldots\ldots$;

$x_2, x_4, x_6, \ldots\ldots$ are the values of x at which the image phase shift coefficient has the values $2\pi, 4\pi, 6\pi, \ldots\ldots$ The numerical values of $x_1, x_2, x_3 \ldots$ can be found by plotting the image phase shift coefficient as a function of x[7]. A convenient method of plotting it for multi-section filters has recently been published.[8]

Acknowledgments.

The author wishes to thank the Engineer-in-Chief, G.P.O., for the loan of the special slide rule for insertion loss calculations, and Mr. J. G. Flint, Chief Engineer of the Telephone Manufacturing Company, for permission to publish this article.

[7] $x_1, x_2, x_3, \ldots$ are values of x at which the insertion loss (neglecting dissipation) becomes zero.

[8] "An Introduction to the Theory and Design of Electric Wave Filters." F. Scowen. Chapter 14.

Moscow Telecommunications Conference

A CONFERENCE of representatives of the U.S.S.R., U.K., U.S.A., France and China was held in Moscow, from the 28th September to 21st October, convened to consider questions of telecommunications. The British delegation were headed by Sir A. Stanley Angwin, K.B.E.

The conference decided that the question of the improvement of the organisation of radio communications and the reallocation of radio frequencies to maritime, aeronautical, long distance land services, broadcasting and other purposes were particularly urgent problems. Particular attention was paid to the consideration of proposals for a new frequency allocation for various services. A common aspect of all the proposals was the attempt to reach technical conclusions which would satisfy all forms of radio communication and improve the present position.

The Conference adopted a recommendation to convene the next World Radiocommunications Conference on the 15th May, 1947, at which these problems would be decided. One of the most important recommendations emerging from the Moscow Conference is the proposal for the establishment of an International Board for the registration of frequencies, comprising representatives of different countries having the necessary technical qualifications and extensive practical experience. The operation of this Board will, it is hoped, reduce mutual interferences between the radio stations of the world.

Questions relating to the organisation of international telephone and telegraph communications were considered, and at the same time the direction in which a revision of the telegraph and telephone regulations should be carried out, with a view to their improvement, was indicated. The Moscow Conference recommends that the World Conference on telephone and telegraph communications should be called in 1948. Consideration of a draft of a new Telecommunications Convention and of the general regulations put forward by the delegation of the U.S.S.R. resulted in a preliminary draft for a new convention.

The Conference recommended that the existing International Telecommunications Union should be reorganised and enter into relationship with U.N.O. An Administrative Council for the International Telecommunications Union would be formed to include a Bureau to control the administrative and technical work of the Union. The Conference recommended that the Plenipotentiary Conference for the acceptance of the new Convention of telecommunications and for the reorganisation of the I.T.U. be convened on the 1st July, 1947. In formulating their suggestions for the World Conference the participants of the Moscow Conference will take into account the recommendations and discussions as recorded in the minutes of the conference.

In order that the work of this Conference can be made of value to all countries of the world in their preparation for the next international conferences, the Moscow Conference decided to distribute these documents to all members of the Union. The work of the Conference was characterised throughout by the utmost degree of collaboration and mutual understanding which augurs well for the successful solution of any problems of telecommunication confronting the next international conference.

Comité Consultatif International Téléphonique, Montreux, 1946

U.D.C. 06.049 : 621.395 654.15

A full Plenary Assembly of the C.C.I.F. met in Montreux from 28th-31st October, 1946, preceded by meetings of all the C.R.s in the week 21st-26th October. The work of the various commissions is summarised in the following paragraphs.

1st C.R.—Protection.

THE first part of Tome II Bis of the White Book agreed at Copenhagen in 1936 was reviewed by the 1st C.R. in the light of the "Directives" (prepared in Rome in 1937 and revised at Oslo in 1938) with the result that the great majority of the avis (Nos. 1 to 14 inclusive and No. 18) were considered to be no longer required.

Since the weighting curve for the psophometer was specified in 1934 considerable progress has been made in the design of subscribers' equipment resulting in a smoother response frequency curve. Although the new type receivers are not available in Europe at present in any great numbers it was decided that, as a matter of urgency, a new weighting curve should be adopted for the psophometer. Experiments have shown that the characteristics of the new European designs and the latest American receivers are similar and to avoid the delay which would inevitably arise if tests were to be made in Europe to determine a new weighting curve, it was agreed to adopt the line weighting curve given in Engineering Report No. 45 of the Joint Sub-Committee on development and research of the Edison Electric Institute and the Bell telephone system. This curve is based on judgment tests made over a period of four years with American telephone sets of very recent design. In the absence of any indication from the U.S.A. of the admissible tolerances for the weighting curve, provisional figures based on those for the existing psophometer were adopted, but these are subject to review when experience of realising the weighting network has been obtained. The revision and completion of other items in the specification of the psophometer was made a question for further study.

It was also agreed to delete the existing definitions and text relating to the unbalance of circuits to earth in Tome III and Tome IV of the White Book and to replace them in Tome III by the corresponding sections of the Directive.

On the question of the value of the fault current to be used in the calculation of the maximum induced voltage (see *P.O.E.E.J.*, Vol. 39, p. 118) it was agreed that the 0·7 factor was illogical, but so far as the admissible limit of induced voltage is concerned it was decided that it should be determined after further study of the risks to which the personnel would be exposed in such cases.

2nd C.R.—Corrosion.

The 2nd C.R. under the chairmanship of M. Popov (U.S.S.R.) reviewed the 2nd, 3rd and 4th parts of Tome II Bis of the White Book and outstanding questions. It was decided to appoint two small sub-committees to revise the "Recommendations" for the protection against (*a*) chemical corrosion, and (*b*) electrolytic corrosion. Representatives of outside bodies representing power, traction and gas interests would be invited to serve on the sub-committees.

It was also proposed to arrange a demonstration, in the suburbs of Paris in the autumn of 1947, of the methods and apparatus used for the investigation of electrolytic corrosion.

3rd C.R.—Transmission.

The 3rd C.R. is preoccupied, as are several other commissions, with three main matters. One is the new volume which will contain all the directives and specifications relative to the European Switching Plan, and the second the modifications to the existing editions of Tome I. The third item is the consideration of questions for study.

After the Paris Conference[1], the sub-commission appointed to study urgent questions met again in London in September, together with some delegates from the 8th C.R. to formulate answers to some questions which it had been found impossible to deal with in Paris. As a result of this meeting several matters were cleared. Amongst these were the frequency allocation for Super Group No. 1 on coaxial systems and the allowable signalling power for various frequencies in the speech spectrum. As a result, the British proposal for Super Group 1 (60-300 kc/s) has been adopted. The whole super group allocation thus remains as recommended by the sub-commission of 1938 and as adopted by the British Post Office. Consideration was also given to a number of maintenance matters relative to wide band systems. A matter which was not settled was the number and frequency allocation of all pilot tones for coaxial systems, although a very useful exchange of views took place. Lower pilot tones of 60 kc/s or 300 kc/s for line regulation and oscillator frequency control were agreed, with an upper pilot at 4,092 kc/s for future use with an interim agreement of 2,604 kc/s for line regulation. It is interesting to note that this envisages an extension of the band beyond that used at the moment in Great Britain, possibly to the 16th Super Group.

The first duty of the 3rd C.R. which met under Mr. R. M. Chamney (Great Britain) was to consider the answers given in Paris and London and recommend to the Plenary Assembly new avis. In general, all the answers were agreed and as a result extensive alterations to Tome I Ter and Tome I Bis will occur. The main items included were given in the Journal[2] in October. An additional item is the target specification for a high quality music circuit which will have a band width of 15 kc/s and improved noise and non-linearity limits.

In addition, a report was made to the Mixed

[1] *P.O.E.E.J.*, Vol. 39, pp. 117.
[2] ibid.

Commission comprising all the directives of transmission relevant to the new European Switching Plan on high velocity cables.

A formidable list of new questions for study was next examined for submission to the Plenary Assembly.

The Plenary Assembly on this subject was presided over by Mr. A. J. Gill (Great Britain) and here the past work was formally ratified and the programme of new work agreed. This consists of 28 new questions in addition to a few old ones, together with work which is bound to devolve as a result of rewriting the various books.

4th C.R.—Quality of Transmission.

The proposals made by the sub-commission for the specification of quality of transmission, at the meeting in Paris, for the immediate steps to be taken with a view to replacing the present volume standard were confirmed. A detailed programme of articulation testing to be carried out at the S.F.E.R.T. laboratory was drawn up, and arrangements were made for the sub-committee to receive the results by post and for the members to discuss them initially by correspondence.

As it was agreed that the term "Effective Transmission" should not be applied to transmission ratings which are not based ultimately on repetition rate tests, some of the terminology, in English, for new techniques of rating will need to be reviewed. Meanwhile the ideas underlying the proposed new form of rating, based on articulation tests, are being carried by the terminology in French.

The existing test (in White Book Tome 1 Ter) dealing with permissible limits of reference equivalents (volume efficiency) of subscribers' and operators' telephones was revised and simplified. A new list of questions to be studied was drawn up.

5th C.R.—Transmission Questions concerning Radio Circuits.

The 5th C.R. met under the presidency of Mr. A. J. Gill (Great Britain). The previous meeting had been at Oslo in 1938, and the questions outstanding at that date were reviewed, and evoked general discussion of considerable interest.

In considering the question of privacy or secrecy equipments used on radio-telephone circuits, attention was drawn to the fact that the commercial equipments referred to are privacy equipments designed to minimise reception by amateurs and not to give protection against professional interceptors. The inverter and band splitting equipments with synchronous switching were scheduled as being in use by various organisations.

It was decided that the question of false operation of echo-suppressors by the noise from radio circuits was not a source of trouble on present-day circuits. Singing suppressors are not normally fitted on land-lines and therefore the original question need not be pursued.

The question dealing with singing suppressors of voice-operated carrier switching devices was left for further consideration but it was recommended that the two parts of the question should be dealt with separately as new questions. A further new question which was the subject of an interesting discussion was initiated. Work is proceeding in several countries with a view to providing telephone facilities to mobile units such as cars in urban areas and ships moving in harbours. Although the extent to which the mobile units will be enabled to communicate as they move from an area in which they are normally registered to other areas is not at present defined, such facilities will be of considerable value to the users and the question deserves international study as soon as is convenient.

6th and 7th C.R.s.—Operating and Tariffs.

The 6th and 7th C.R.s met together under the chairmanship of Mr. Moeckli (Switzerland) for the operating questions and Mr. Santing (Holland) for the tariff questions.

These C.R.s examined the Operating and Tariff avis in the Green Book (Cairo, 1938) and the Pink Book (London, 1945) with a view to the issue of a new edition to be known as the Yellow Book (Montreux, 1946). Certain of the avis were revised to comply with the new requirements of Rapid International Service, some were cancelled and certain other rearrangements made.

The draft instruction for operators for the International Rapid Telephone Service prepared in Paris in June was accepted, as also was the list of additional operating phrases. The new edition of the operating phrases will be published in eight languages.

It was agreed that a list should be prepared of the categories of calls admitted by countries in the various European International Telephone services. On the other hand, it was considered premature at present to issue a list of normal, auxiliary and emergency routes and it was decided that full particulars of circuits projected as existing at 1st January, 1948, should be supplied so that a complete list may be prepared by the C.C.I.F. during 1948.

The proposal by the Swedish Administrations to use the name "erlang" for the unit of intensity of traffic was adopted.

8th C.R.—Signalling.

The 8th C.R., under the chairmanship of Mr. Holmbladt, gave detailed attention to the matters dealt with at the Paris[3] meeting, and presented their report to the Plenary Assembly for inclusion in the new directives concerning the European Switching plan.

The data to be examined to determine the choice of frequency for international signalling is expected to be available early in 1947, and it is proposed to hold a meeting in Paris during the summer of 1947 to decide the point.

At the Montreux meeting a complete review was made of outstanding matters relating to international signalling and as a result 16 questions were scheduled for attention and discussion before the next Plenary Assembly.

The questions cover all matters where, as far as can be foreseen, international agreement will be necessary.

[3] loc. cit.

Mixed Commission for the European Switching Programme.

Probably the most urgent of the many post-war tasks of the C.C.I.F. is to try to reach agreement between countries on the guiding principles for the reorganisation of the European cable network to meet the needs of post-war international telephone services. To facilitate a thorough study of the problem a Mixed Commission was specially constituted at the London meeting in 1945 under the chairmanship of M. Gastebois (France). Much progress had already been made in collecting necessary information as to existing and proposed cables and also the individual requirements of the various countries by 1952. Its own directives on the new switching plan, as well as those prepared by the other commissions, were studied at Montreux with a view to preparing a single comprehensive directive on the subject covering (*a*) operating, (*b*) transmission. (*c*) signalling, (*d*) maintenance, and (*e*) routing.

The basis of the new European Switching Plan is a high velocity network either coaxial or 12-channel, and the plans of most countries are now taking shape. Great Britain, for example, which already has high speed cables to France and Holland, is planning to augment these and lay a new concentric cable to Belgium.

Permanent Maintenance Sub-Commission.

This sub-commission met under the chairmanship of M. Visser (Netherlands Administration) and the following items were discussed :—

(1) *Maintenance of International 12-channel Groups :* Procedure for the maintenance of such groups had been proposed by Great Britain at the June meeting in Paris. In the meantime, this had been edited for insertion into the White Book, and the proposed drafts were agreed by the 3rd C.R. and the Plenary Assembly. The proposals now have international standing.

(2) *Hypsograms for International Circuits:* Modifications to the pre-war hypsograms were discussed and agreed to bring them into line with modern practice. The type of loading and type of cable has been omitted and in its place the transmission time and effective band width of the circuit has been substituted. The method of indicating a carrier circuit in a 12-channel group on the hypsogram was also agreed.

(3) Consideration was given to the production of a hypsogram for an international 12-channel group. Since the principal levels of an international 12-channel group have been standardised by the 3rd C.R. it is considered that a simpler form of record could be used. Great Britain had submitted a suitable draft which, with minor modifications, was agreed internationally, and will be known as "Acheminement du Groupe à douze voies." This also was agreed by the 3rd C.R. and the Plenary Assembly and will become the international record for such groups.

(4) The international numbering series for 12-channel groups was also discussed and agreed. All international 12-channel groups will in future be numbered in the 900 series, commencing at 901. This is very similar to the method adopted in Great Britain.

(5) The maintenance programme of all existing and projected international circuits which transit more than one country, was drawn up and agreed. This programme indicates the dates and periodicity of tests of all such international circuits.

Symbols Commission.

The Symbols Commission considered several proposals concerning letter and graphical symbols.

Probably the most important letter symbols under consideration were those for the propagation, attenuation, and phase-change coefficients. In many European countries β = attenuation coefficient, and α = phase-change coefficient, while in others α = attenuation coefficient and β = phase-change coefficient. In all countries there has been the drift towards using Roman letters instead of Greek letters, mainly for the practical reason that Roman letters are provided on typewriters.

After discussion with the 3rd C.R. it was agreed that for C.C.I.F. documents in the future the following letter symbols would be used :—

Propagation coefficient	per	unit	length	= p
Attenuation	,,	,,	,,	= a
Phase-change	,,	,,	,,	= b

and hence $p = a + jb$.

For a total length l

$P = pl = A + jB$.

It was agreed that all countries would examine the possibility of changing to the above symbols for their own national usage.

It was agreed that a series of letter suffixes prepared by the Symbols Commission should be studied by the several C.R.s of the C.C.I.F., C.C.I.T. and C.C.I.R. For instance, although Z was generally accepted as the symbol for impedance there were many variations in the suffixes used to denote, say, closed circuit impedance, open-circuit impedance and characteristic impedance. The suffixes used were generally abbreviations of the words of the language of the author. The Symbols Commission proposed a standard list of letters for universal usage.

As regards graphical symbols the most important were :—

(*a*) those for coaxial cable and for equipment used with it, and

(*b*) symbols for use in frequency spectrum diagrams.

These graphical symbols were approved by the C.C.I.F. and will be recommended to the International Electro-technical Commission (C.E.I.) for international adoption.

As may be surmised, the work was carried on in very congenial surroundings. Every effort was made by the Swiss Administration to make the stay as pleasant as possible by arranging excursions for the ladies during the week, and excursions for all on off-days. Particularly enjoyable were the visits to the old castle of Chillon and to the mountain resort of Gstaad.

The Telecommunications Development Scheme of India

MAJOR L. J. REECE
(Attached Indian P. & T.)

U.D.C. 621.39 (54)

A brief outline of the extension of Indian telecommunication facilities during the period 1942-1946.

Introduction.

DURING the early part of 1942 it had become obvious that the telecommunications facilities of India were wholly inadequate to meet the needs of a country which had to be developed as a base from which an attack could be launched against Japan, and which had in the meantime to be defended against attack. The fighting services needed administrative and operational telecommunications; the civil administration and commercial interests needed improved communications to enable them to support the fighting services and maintain their supplies.

Telecommunications Development Scheme.

A Defence Services Line Communications Board (D.S.L.C.B.) was formed to co-relate the requirements of the Defence Services for line communications, and to decide upon the relative priority with which such communications should be provided. This Board was formed by the Signals Directorate of India G.H.Q. and had a military officer as President, and a representative of the Indian Posts and Telegraphs as a member. In addition the Government of India formed a Board, known as the Telecommunications Development Board (T.D.B.), which was instructed to prepare a rough project and project estimate of a scheme for the development of India's telegraph and telephone communications to meet both civil and defence requirements during the war.

A scheme was produced and sanctioned in June, 1942, but was revised and enlarged in January, 1943, to include the "regional" works of the War Department, and certain additions to the "main network." The main provisions of the revised scheme were roughly :—

Wire	273,000 miles
Posts	648,000
Telephone circuits (Carrier channels)	402
Telegraph circuits (Voice frequency)	354
Auto Exchange Plant	18,000 lines
Subs. telephone instruments ..	20,000
Buildings .. .. costing	£375,000

This scheme was approved, and has now to a large extent been completed (see Figs. 1 and 2). There was a broad division of the scheme into "Main Network" and "Regional Works," the former comprising the joint requirements of the War Department and the P. & T. Department for long distance telephone and telegraph circuits, and the latter being the War Department local circuit requirements.

The amount of work to be done rendered it impossible for all detailed planning to be carried out at the headquarters, and decentralisation was therefore effected by dividing the country into four "areas," each area having a controlling Installation Engineer, who was responsible for planning and installations at all stations in his own area. This system worked very well, its only disadvantage being that there was a lack of uniformity in installation methods, and some effort will now have to be made to standardise the network.

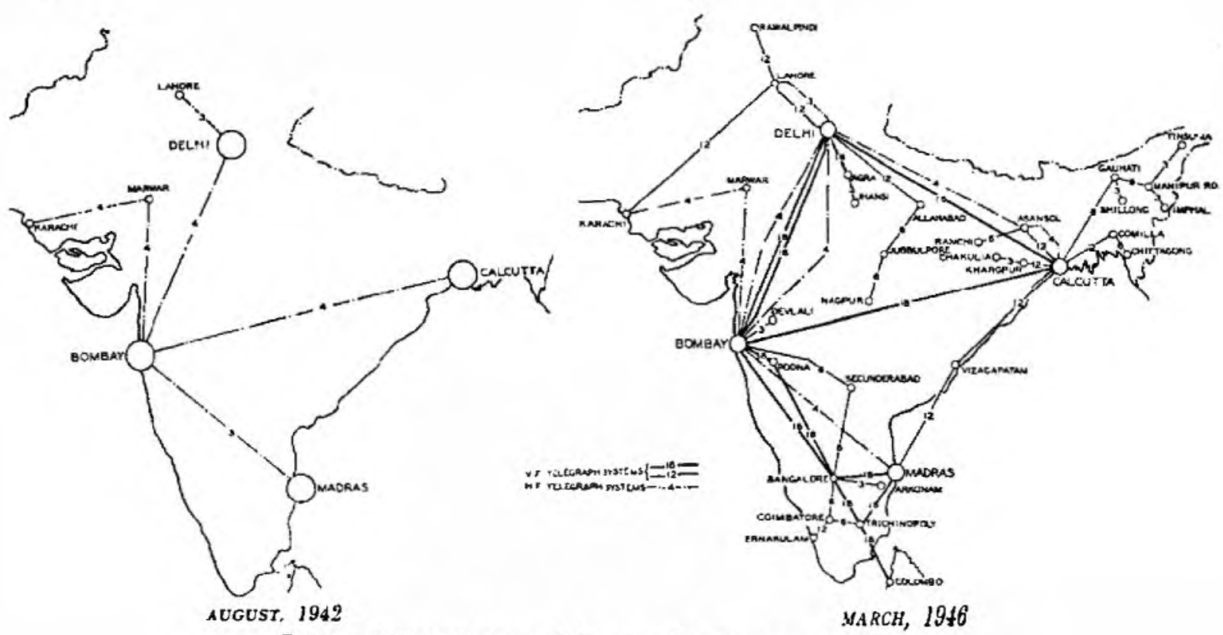
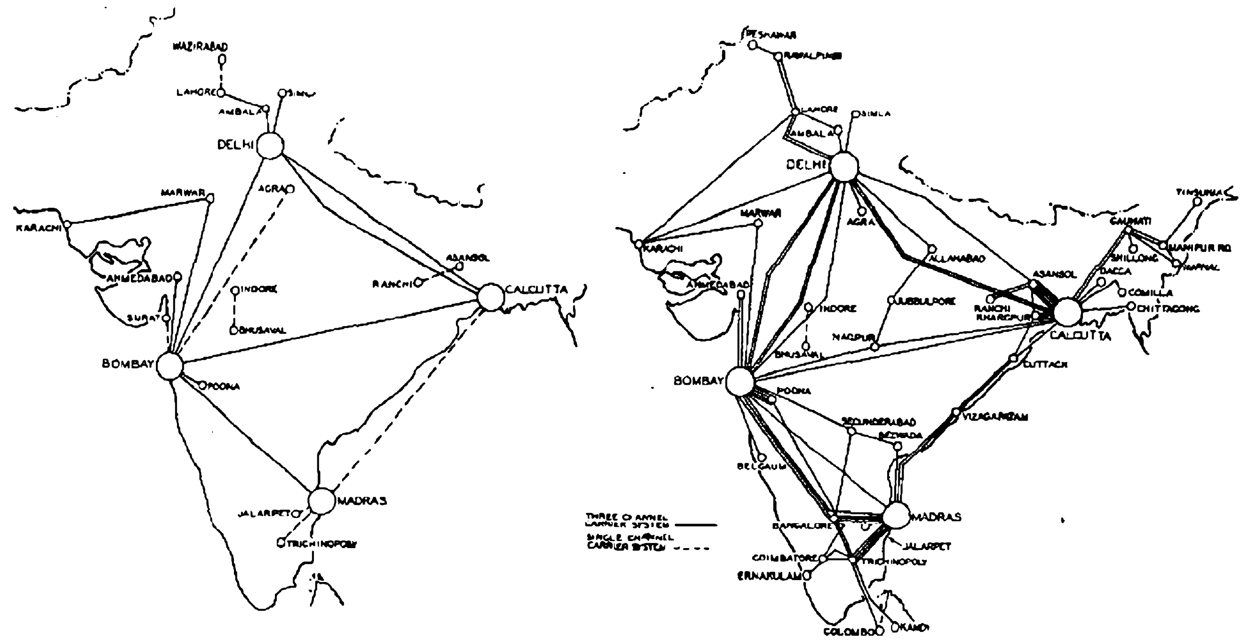


FIG. 1.—DEVELOPMENT OF V.F. AND H.F. TELEGRAPH SYSTEMS.



AUGUST, 1942 MARCH, 1946

FIG. 2.—DEVELOPMENT OF CARRIER TELEPHONE SYSTEM.

Installation Difficulties.

Difficulties of all kinds were, of course, experienced and their treatment required individual attention. For instance, a large number of wide rivers had to be crossed, and this was usually done by fixtures on bridges. Each bridge had to be treated specially, since no two bridges were alike. Where bridges did not exist, special masonry piles had to be constructed in the river bed to carry the route. A new type of line construction for carrier circuits was evolved, which was efficient in all respects. No existing routes were suitable and construction officers had to be given special training before the work could commence. The supply of stores was a constant source of anxiety, due to shortages of raw materials, etc., and the position became more strained when large parts of stocks had to be handed over to South-East Asia Command, for the execution of the war in Burma. Despite these difficulties, however, the scheme gradually went forward, until to-day it is all but complete.

Maintenance Problems.

Maintenance of systems when once they were put into service proved to be a big problem, because of the lack of fully trained maintenance staff. This applied only to carrier equipments, since with V.F. telegraph systems the equipment was installed and afterwards maintained by D.T.N. sections of the Royal Signals. The inexperienced maintenance personnel were helped to a great degree on the maintenance of carrier equipments by the installation parties, but the problem soon became of such dimensions as to render this practice unworkable, and a special Maintenance Section was formed, made up of technicians drawn from the installation side. This section is now working smoothly, and has grown into four maintenance groups, one in each area headquarters. V.F. telegraph installations are still being maintained by Army personnel, but P. & T. staff is being trained, and they will in time take over all such equipment in India.

Acknowledgments.

Speed was, at all times, of the first importance, and to this end very valuable assistance was rendered by the following administrations :—

1. Burma Posts and Telegraphs. The Chief Engineer and a number of his officers did much valuable planning and surveying work from August, 1942, to July, 1943, and again from March to September, 1944, as well as construction work on the Trichinopoly-Bangalore-Madras alignments.
2. Royal Signals. Most of the work of installing carrier telephone and voice frequency telegraph systems and the installation and design of trunk exchanges was carried out under the direction of Royal Signals officers, and their standards of workmanship were excellent.
3. Telephone Manufacturers. The British Telephone Manufacturers lent highly qualified transmission and switching engineers, who acted as technical advisers and supervised installation works, including the installation of three of the largest trunk exchanges forming part of the scheme. All this help was of immense value.
4. Indian P. & T. Department. Much credit is due to all ranks of the Indian Posts and Telegraphs, who have worked unremittingly for over three years on the Telecommunications Development Scheme. Special mention must be made of the staff who worked in East Bengal and Assam during the crucial years of 1943 and 1944.

Notes and Comments

Roll of Honour

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

While serving with the Armed Forces.

Canterbury Telephone Area	Freeborn, A. R...	Skilled Workman, Class II ..	Signalman, Royal Signals
Engineering Department ..	Willcocks, E.W.H.	Skilled Workman, Class II .. (Unestablished)	Flight Sergeant, R.A.F.
Glasgow Telephone Area ..	O'Donnell, H. P.	Unestablished Skilled Workman	Signalman, Royal Signals
Leicester Telephone Area ..	Jackson, D. S. ..	Unestablished Skilled Workman	Corporal, Green Howards
Liverpool Telephone Area ..	Green, L. D. ..	Unestablished Skilled Workman	Sub.-Lieut., Fleet Air Arm, R.N.
London Telecoms. Region ..	Ffrench-Kahoe, C. J.	Unestablished Skilled Workman	Flying Officer, R.A.F.
London Telecoms. Region ..	Fowler, A. J. ..	Unestablished Skilled Workman	Ldg. Telegraphist, R.N.
London Telecoms. Region ..	Talbot, A. J. ..	Unestablished Skilled Workman	Signalman, Royal Signals
Middlesbrough Telephone Area	Birkett, W. N. ..	Unestablished Skilled Workman	Flight Sergeant, R.A.F
Newcastle-on-Tyne Telephone Area	Patton, G. ..	Labourer..	Corporal, C.M.P.
Sheffield Telephone Area ..	Chatterley, J. S...	Labourer..	L/Cpl., Manchester Regt.
W. and B.C. Region ..	Moore, J. K. ..	Draughtsman, Class II.. ..	Major, Royal Signals

Recent Awards

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

Birmingham Telephone Area	Berresford, B. H.	Inspector ..	Major, Royal Signals	Twice Mentioned in Despatches
Birmingham Telephone Area	Eccleston, L. D.	Skilled Workman, Class II	R.S.M., R.A.	Belgian Croix de Guerre, 1940, with Palm
Birmingham Telephone Area	Ganderton, W. G.	Inspector ..	Sergeant, Royal Signals	Mentioned in Despatches
Bournemouth Telephone Area	Quilty, M. J. T.	Skilled Workman, Class II	Corporal, Royal Signals	Mentioned in Despatches
Bradford Telephone Area ..	Broadbent, F. ..	Skilled Workman, Class I	Wt. Offr. Class II, Royal Signals	Mentioned in Despatches
Bradford Telephone Area ..	Hargreaves, T. R.	Unestablished Skilled Workman	B.Q.M.S., R.A.	Belgian Croix de Guerre, 1940, with Palm
Bristol Telephone Area ..	Symonds, S. G.	Skilled Workman, Class I	Elect. Artificer, 1st Class, R.N.	British Empire Medal
Edinburgh Telephone Area	Anderson, G. O.	Skilled Workman, Class I	C.S.M., Royal Signals	Mentioned in Despatches
Engineering Department ..	Cole, A. C. ..	Clerical Officer ..	L/Corporal, Royal Signals	Mentioned in Despatches
Engineering Department ..	Hutchinson, E.	Motor Mechanic..	Wt. Offr., Class I, R.E.M.E.	Mentioned in Despatches
Engineering Department ..	Millson, H. W...	Inspector ..	Fl. Officer, R.A.F.	Mentioned in Despatches
Engineering Department ..	Pitman, L. W. J.	Unestablished Draughtsman	Corporal, Royal Signals	Mentioned in Despatches
Engineering Department ..	Wood, T. E. ..	H.C.O.	Captain, R.E. (P.S.)	Mentioned in Despatches
Engineering Department ..	Wright, H. C. ..	Inspector ..	Major, Royal Signals	Mentioned in Despatches
Leeds Telephone Area ..	Ward, H. B. ..	Skilled Workman, Class II	Corporal, Royal Signals	Mentioned in Despatches
Leicester Telephone Area ..	Rumbellow, V. G.	Inspector ..	Captain, R.E.M.E.	Mentioned in Despatches
Liverpool Telephone Area ..	Rogers, J. ..	Skilled Workman, Class II	Fl. Officer, R.A.F.	Distinguished Flying Cross

London Telecoms. Region ..	Buckland, L. R. M. ..	Skilled Workman, Class II	Signalman, Royal Signals	Mentioned m Despatches
London Telecoms. Region ..	Haarer, P. E. ..	Skilled Workman, Class II	C.Q.M.S., Royal Signals	Mentioned in Despatches
Midland Region	Border, W. A...	A.R.M.T.O. ..	Major, R.E. (P.S.)	Member of the Order of the British Empire
Newcastle-on-Tyne Telephone Area	Cant, E. ..	Skilled Workman, Class II	L/Sergeant, Royal Signals	Mentioned in Despatches
Scotland West Telephone Area	*Arnott, J. ..	Unestablished Skilled Workman	L/Sergeant, Royal Signals	Mentioned in Despatches
Scottish Region	Bucknall, F. R. B. ..	Power Engineer..	Captain, Royal Signals	Mentioned in Despatches
Southend-on-Sea Telephone Area	Eighteen, E. W.	Labourer.. ..	Flight Lieut., R.A.F.	Distinguished Flying Medal
Stoke-on-Trent Telephone Area	Davis, T. H. ..	Unestablished Skilled Workman	Sergeant, Royal Signals	Mentioned in Despatches
Swansea Telephone Area ..	Griffiths, C. P...	Skilled Workman, Class II	Signalman, Royal Signals	Mentioned in Despatches
York Telephone Area ..	Fish, H. W. ..	Skilled Workman, Class II	Sergeant, Royal Signals	Croix de Guerre with Palm

* Died 24th August, 1945, while a P.O.W.

The Retirement of Mr. F. O. Barralet

Frank Owen Barralet entered the Post Office Engineering Department in January, 1900, and served with the Test Section of the Engineer-in-Chief's Office until 1910. After a short period in the London District he joined the Research Section in 1914.

Among the work for which he will be chiefly remembered are the development and production during the first world war of hot wire microphones for gun ranging; the introduction into the new Dollis Hill laboratories of many optical and spectrographic aids to analysis; his researches on the metallurgy of lead and the development of the palladium chloride gas indicator. These achievements earned him expressions of appreciation from the Army Council and the Postmaster-General, and in 1925 the I.P.O.E.E. awarded its Senior Bronze Medal to him for a paper describing some of this work.

Mr. Barralet left Dollis Hill in 1933 to return to the Test and Inspection Branch as Staff Engineer. The second World War brought him many additional responsibilities and doubled the value of stores tested annually by his branch.

Mr. Barralet represented the Post Office on a number of committees and is well known to engineers and scientists outside the Post Office. The good wishes of these, of his colleagues in the Post Office and particularly of his staff, in whose careers he always took a kindly interest, will be with him as he commences a well-earned retirement.

W. G. R.

Mr. S. Hanford, B.Sc., M.I.E.E.

Mr. S. Hanford, who succeeds Mr. F. O. Barralet as Staff Engineer of the Test Branch, is a native of Burton-on-Trent. Educated at the Grammar School there, and later at Birmingham University, he entered the Engineering Department by Open Competition as an Assistant Engineer in 1911. His first appointment was to the Engineer-in-Chief's office where he served successively in the Test and Lines Sections with a break for service in the R.E. Signals in the first World War. In 1929 he was transferred to the Canterbury Section, returning to the Chief's office in 1931 on promotion to Executive Engineer in the Research Section.

Here he was in charge of the Cable Test Section and went with it on its transfer to the Test Branch in 1934, being promoted to Assistant Staff Engineer there in 1937. He rejoined the Royal Signals during the recent war, serving in France and Germany, being engaged mainly on the construction of main cable routes.

Throughout his service Mr. Hanford has been closely connected with cable matters. His early years in the Test Section were largely occupied with the design and specification of the then rapidly developing paper-insulated cable. These, subjected to minor modification from time to time, have remained standard ever since. On his rejoining the Test Branch in 1934 it was his interest and enthusiasm which resulted in the Cable Test Section being installed in ample and suitable premises, and its equipment and personnel being built up to a level worthy of the Department.

As an Assistant Staff Engineer his interests widened to embrace all sides of line plant matters, and there is no doubt that his active personality will enable him to take an effective part in all sides of the Test Branch's activities. Finally, his sympathetic approach to staff matters should ensure his success with the large staff which now comes under his control.

H. J. D.

Sir Frank Gill

Everyone in the telecommunications industry will be most gratified to hear that at the Plenary Assembly of the C.C.I.F. at Montreux, Sir Frank Gill, K.C.M.G., was elected to be an honorary delegate to all future meetings. This honour, which was also conferred on M. Muri, has only once before been conferred, to M. Fossion of the Belgian Administration.

Sir Frank Gill has taken a leading part in the industry for more than 40 years, and there is perhaps no one who could rival his knowledge, and indeed his energy, still so evident, in spite of his long service.

The Royal Statistical Society

In 1945 the Royal Statistical Society formed an Industrial Applications Section concerned with the application of statistical techniques to all aspects of industry with local groups in Birmingham, London and Sheffield.

The Society now reports that a North-Eastern Group has been formed, centred on the Tyne and Wear areas, and including a Tees-side sub-group. The honorary secretary of the new group is Mr. J. Elliott, Lemington Glass Works, Lemington-on-Tyne, Northumberland; and of the sub-group Mr. J. T. Richardson, Research Department, Imperial Chemical Industries, Ltd., Billingham, Co. Durham.

Mr. W. J. Bailey, M.I.E.E.

It is with regret that we record the death, in November, 1946, of Mr. W. J. Bailey. He joined the Central Telegraph Office as a telegraphist in August, 1885, passed the Civil Service examination for Second Class Engineer in April, 1908, and joined the Designs Section of the Engineer-in-Chief's office, G.P.O., in April, 1909. Here he took a very active part in the introduction of the first automatic exchanges and wrote comprehensive technical descriptions of the Strowger and Lorimer systems which were published in this JOURNAL, Volumes V and VI.

In March, 1927, he was appointed Staff Engineer in charge of the Equipment Section controlling the design and provision of automatic exchanges.

Mr. Bailey initiated the Equipment Section Swimming Club, and was one of its keenest members. Every week, summer and winter, until he retired in June, 1931, at the age of 60, he swam at the baths. The "Bailey Cup" which he presented for annual competition will remain as a memento of a kindly and considerate personality who will be remembered with affection by many of the staff of the Telephone Exchange Contractors and the G.P.O. Engineering Department.

J.R.

Cable and Wireless Ltd.

As reported elsewhere in this issue Sir Stanley Angwin, K.B.E., D.S.O. is relinquishing his post as Engineer-in-Chief of the Post Office to become Chairman of the new board of directors appointed for Cable and Wireless Ltd. upon their transfer to national ownership. He will be joined there by Mr. J. Innes, C.B., who, becomes Managing Director of the company.

Mr. Innes has, since 1942, been Deputy Secretary at the Ministry of Fuel and Power. Prior to that date he was in the Post Office reaching the rank of Assistant Engineer-in-Chief before transferring to the administrative side, where he became Director of Telecommunications. Mr. Innes was for many years Managing Editor of this JOURNAL.

Book Review

"Photoelectric Cells." A. Sommer, D.Phil. 104 pp., 27 ill. Methuen & Co., Ltd. 5s.

This addition to the Methuen's Monographs on Physical Subjects describes photoemission and photoemissive cells. It is welcomed. During the last ten years text-books have tended to ignore photoelectricity, a subject whose outstanding problems none the less deserve attention. Photoemission from clean metals, though well understood, is of little use to the telecommunications engineer whose most easily controlled radiations—the visible and the infra red—here produce little or no useful effects. But photoemission from a few particular composite surfaces, though of much use to the engineer in sound reproduction, television, etc., presents problems, to both the physicist and the engineer, whose solutions are still only qualitative.

Thus, when in two of the opening chapters the author describes the theory of photoemission and the properties of commercial photoelectric cathodes, his explanations of the physical processes are largely qualitative. Chapters on the matching of light sources and photocathodes and on the mechanism of gas amplification follow and will appeal to the engineer. Multiplier cells are then given a fair share of attention; the author makes it clear that they are not always superior to the simpler cells. The last chapter, devoted to the applications of photocells, will assist the choice of cells for use in photometry and telecommunications; the description given of television "pick-up" tubes is brief, but any defect is alleviated by a good bibliography. Throughout, the author does a good service in pointing out the limitations of each cell described.

The book fulfils the aims of the publishers and it is, in general, very readable. Occasionally the clarity suffers when explanations of experimental data are given; and careful editing, by removing many pointless phrases, mostly introductory, would shorten the book by several pages.

J. R. T.

Institution of Post Office Electrical Engineers

Stoke Sub-Centre

The present session was initiated with a most successful visit to the English Electric Co's works at Stafford on 24th October, when 30 members availed themselves of the opportunity of seeing heavy current electrical engineering equipment in production.

It was possible to see all stages of construction of turbo-alternators, including the make up of stators from laminations, the milling of rotors and the insertion of windings. The dynamic balancing of rotors was a feature of interest to all.

The production of high voltage switching gear was also examined, including a new design of breaker employing compressed air to blow out the electric arc. The production of very large power transformers was also seen, and the associated switching gear for maintaining steady voltages at the distant end of transmission lines was of particular interest.

The destinations of the items being produced surprised some, and the quantity of equipment going to the U.S.S.R. was noticeable. Other machines were destined for South Africa, New Zealand and for home use.

The Research Laboratories of the firm were also visited, and an examination was made of very high voltage testing equipment, together with X-ray equipment used for testing of the crystalline structure of metals and examination of apparatus manufactured by the firm.

Experiments were also being conducted on air-tight seals for the anodes and grids of steel tank rectifiers.

The factory management dealt with the visit most efficiently, sufficient guides being provided from University Graduate Trainees to enable small parties of three or four members being given excellent individual attention.

After partaking of an ample tea as the guests of the Company, the members returned to Stoke well satisfied with a most interesting visit.

E. A. M.

Institution Library

Recent additions to the Library include the following

1707 *Theory cf Gaseous Conduction and Electronics.* Maxfield and Benedict (American 1941).

A textbook covering the fundamentals of conduction in gases and suitable for undergraduate students in electrical engineering and applied physics. This book discusses not only high vacuum conduction as found in radio tubes, cathode-ray tubes and phototubes, but also the theory and application of corona, sparking, glows and arcs.

1708 *Heaviside's Electric Circuit Theory.* H. J. Josephs (British 1946).

Covers foundations of electric circuit theory and the use of Heaviside's theorem in the analysis of electric circuit problems.

1709 *Ultra High-Frequency Radio Engineering.* Emery (American 1944).

A book for senior electrical engineering students, and assumes a general background in elementary communication and electronics. Emphasis of treatment is on the discussion of the component parts of ultra high-frequency systems. Scope covers voltage-regulated power supplies—electronic switching and synchronisation—cathode-ray tubes and sweep circuits—amplifiers—square wave testing and transient response—ultra H.F. circuit elements—oscillators—modulation and detection—radiation and waveguides.

1710 *Electronics.* Millman and Seely (American 1941).

A textbook of broad scope with emphasis on fundamental theory and the physics of electronic devices. Useful also where the principal objective is the study of the technical and engineering applications of these devices. Theoretical and practical aspects of electronics are included side by side, presenting a unified treatment of interest to students of either physics or engineering.

1711 *Waveform Analysis.* Manley (British 1945).

This book gives practical information on the interpretation of recorded waveforms and allied subjects, and is in the nature of a guide to the interpretation of periodic waves including vibration records. The special object has been to present in detail the envelope method of analysis which enables recorded waveforms to be analysed into their principal constituents without having recourse to mechanical contrivances or to the more exact but cumbersome methods usually known as "Fourier analysis" or "Harmonic analysis."

1712 *Transmission Lines, Antennas and Wave Guides.* King, Mimno and Wing (American 1945.)

Treatment is concise and largely non-mathematical. The chapter on transmission lines is devoted mostly to the dissipationless line and impedance matching devices, whilst the subjects of antennas and ultra H.F. circuits have been so treated to develop a real understanding for the electromagnetic point of view. The section on wave propagation, however, is brief and is intended primarily for students with a general knowledge of physics who have had no previous opportunity to study the basic principles of radio transmission.

1713 *Science since* 1500. Pledge (British 1940).

Covering in a general way science and pre-science from ancient Greece to the second Renaissance—biology before the microscope—astronomy before the telescope—mathematics before the calculus—mechanics, astronomy, optics (especially in the 17th century), mathematics (1600-1800)—microscopy, classification, geology—experimental science—mathematical physics—evolution and the microscope—19th century mathematics—organic chemistry—surfaces and ions—cytology and genetics—growth and unity of the individual—ecology—modern experimental physics—quantum theory—relativity and cosmology—real materials.

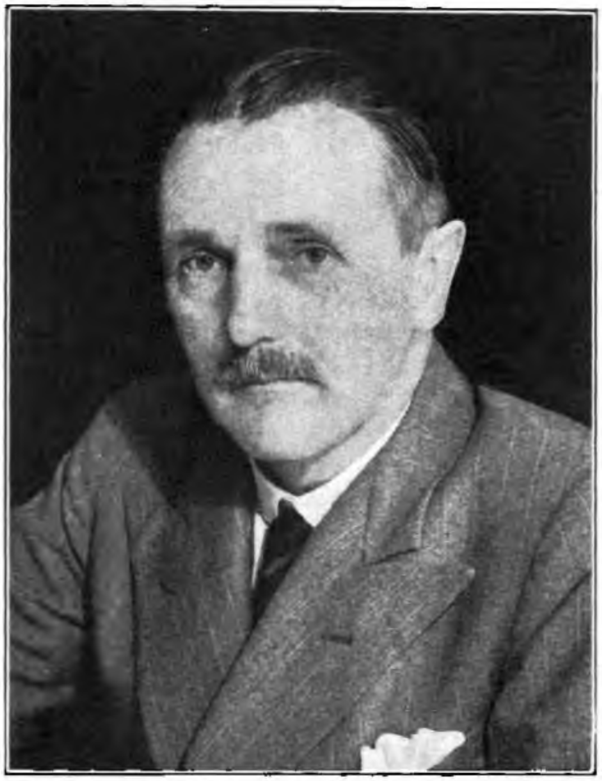
1714 *General Principles cf the Quantum Theory.* Temple (British, 1946).

An introductory account. This theory is considered here as a branch of physics and not as a branch of mathematics.

1715 *Advanced Mathematics for Technical Students (Part 1).* Geary, Lowry and Hayden (British 1945).

Suitable for students of science or engineering who have reached the standard of a University Intermediate examination or an Ordinary National Certificate in engineering. The work includes a chapter on approximate methods and fundamental principles of mechanics in which vectors and calculus are used from the outset. Although some knowledge of the calculus is assumed, the chapters on differentiation and integration start from the beginning.

Col. Sir A. Stanley Angwin, K.B.E., D.S.O., M.C., T.D., M.Inst.C.E., M.I.E.E.



Col. Sir A. Stanley Angwin, who now relinquishes the post of Assistant Director-General and Engineer-in-Chief, has held office since June, 1939, and has directed the work of the Engineering Department during the most momentous days of this country's history. It was, indeed, a fortunate circumstance that the direction of affairs at such a time was in the hands of one so competent to guide the work of Post Office Engineers to ensure the utmost contribution to the war effort.

During his period of office many important technical developments in the work of the Department have taken place. These include the adoption of coaxial cable systems as a normal method of providing trunk line communications, the adoption of "two voice-frequency" signalling between zone centres and the use of submerged repeaters on submarine telephone cables.

Sir Stanley's wide knowledge of military signals requirements and his extensive experience in the regular and territorial army enabled him to be of exceptional assistance to the fighting services, not only in advising them as to the most suitable types of equipment, but also in providing for them the most suitable personnel from his own staff to fill important positions in connection with these services. He represented the Post Office on the Radio Board and was Chairman of the Transmitter Committee of that Board which controlled the production and allocation of radio transmitters for all purposes.

Early in 1945 Sir Stanley accompanied Lord Reith on an air tour to all the Dominions to discuss with the Commonwealth Administrations proposals for modifying the character of Cables & Wireless, Ltd. This trip was exceptionally arduous and involved three crossings of the Atlantic and a total of 44,000 miles flying in a period of 6 weeks.

Sir Stanley's wide knowledge and experience on International Telecommunications matters has entailed many other journeys during the last few years, notably to the United States in the summer of 1945 and to Bermuda in November, of the same year. In January, 1946, he visited Germany and later attended a Telecommunications Conference of the senior allied powers at Moscow.

Sir Stanley has for many years been an active member of the Institution of Civil Engineers and of the Institution of Electrical Engineers. He is a member of Council of both Institutions and was President of the Electricals in 1943, a responsibility doubly difficult in view of his other work during the war period.

Sir Stanley has always taken a keen interest in educational matters, and for some years has been a member of the Board of Engineering Studies of the University of London. Recently he has been honoured by being made a fellow of Queen Mary's College—his Alma Mater.

Sir Stanley is indefatigable, and while unsparing of himself is always most considerate for those who work for him, to whom he is an inspiration and a guide, philosopher and friend. He leaves us to take up the post of Chairman of Cable & Wireless, under its new role of a Government-owned concern, and he carries with him the good wishes of all his old colleagues.

A. J. G.

Mr. A. J. Gill, B.Sc.(Eng.), M.I.E.E., F.I.R.E.

Mr. A. J. Gill, who succeeds Sir Stanley Angwin as Assistant Director General and Engineer-in-Chief, joined the firm of Yarrows, Engineers and Shipbuilders in 1906, as a pupil, leaving them in 1910 to gain experience of steam turbine design with the British Thomson-Houston Co. Following success in the Open Competition, he joined the Post Office as Assistant Engineer in April, 1913, being appointed to the Radio Branch and taking, in due course, a prominent part in the construction and development of the Leafield and Rugby radio stations In March, 1925, he was promoted to Executive Engineer and took charge of the Radio Experimental Laboratories at Dollis Hill. From December, 1929, he was Assistant Staff Engineer in charge of the planning, development and experimental sections of the Radio Branch until in December, 1932, he became Staff Engineer of the Branch. Certainly no one had cause to complain of the enterprise of the Branch, and its plentiful fund of ideas which resulted from his direction. It must have been with a certain feeling of sadness that he received his promotion to Assistant-Engineer-in-Chief in July, 1938, after twenty-five years' concentration on all the many activities, business and social, of the Radio Branch. Until his promotion to Deputy Engineer-in-Chief in January, 1944, the Lines, Construction, Power, Radio Maintenance and Development Branches reported direct to him, but after this date only the Submarine Cable Section of the Lines Branch and both Radio Branches continued to report direct.

Even now it is difficult to disclose and detail the many and varied activities of Mr. Gill throughout the war years, and it must suffice to say that he was the Post Office representative on the Optec Committee of the Radio Board, played a large part in the planning of deep level tunnels for the safeguarding of communications, was mainly responsible for the specification of our latest and largest cable ship, the *Monarch*, as well as being involved in the design of the many radio stations erected by the Department during the war. He has also found time to act as Chairman of the Telecommunications Symbols and Nomenclature Committee of the B.S.I., and lately as principal rapporteur of the Fifth Commission of the C.C.I.F. ; he is also interested in the C.C.I.R He is a Vice-President of the Institution of Electrical Engineers.

Needless to say, Mr. Gill is highly popular with his colleagues, who feel confident that even his appointment as Engineer-in-Chief will be quite unable to stem that free flow of ideas and original approach to problems which, in addition to a well-developed sense of humour, are so characteristic of the man.

A. H. M.

Junior Section Notes

Bristol Centre

The season opened with a summer visit to the Pirelli General Cable works at Eastleigh, Southampton. A keen interest was displayed by the members who watched with fascination copper ingots being rolled into wire, insulated with paper and finally formed into cables.

Our thanks are extended to the Department for their collaboration and to the staff of Pirelli, Ltd., for the outstanding success of the visit.

A paper on "Centimetre Radar" was read by Mr. R. E. Griffin at the October meeting. This was extremely interesting, well read, and showed that the speaker had a firm grasp of his subject. Exhibits ranging from acorn valves to magnetrons and cavity resonators were keenly inspected by the members.

Attendances at the monthly meetings leave much to be desired, due to many members attending evening classes, which are held each night of the week. For those who can attend, a full and comprehensive programme, which includes outside visits, has been arranged.

A welcome is extended to visitors and to students at the Regional Training School, Shirehampton.

Chiltern Area Centre

The Chiltern Area Centre, which covers the Aylesbury, High Wycombe and Amersham areas, is now functioning. The centre was formed in 1939, but due to its being a widespread area, was not able to carry out any programme during the war years.

The elections of officers for the 1946/7 session are as follows: Chairman, F. Sherriff; Vice-Chairman, E. V. Shepherd; Secretary and Treasurer, L. B. Slatter. Committee: A. H. Gwilliam, D. H. Noble, A. C. F. Leadbitter, W. J. Osborne, R. R. Raynor, and A. J. Pearce.

Our first meeting was held at Aylesbury on 14th October, 1946, when a most interesting lecture was given by our Area Engineer, Mr. A. G. Robins, A.M.I.E.E., on "The Development of our Trunk Cable Network."

Other papers promised for the session are as follows: "Decibels," J. Williams; "Model Engineering" and practical demonstrations, F. R. Forest; "Amplifiers," A. C. F. Leadbitter; "Projectors," H. J. Trotman.

L. B. S.

Edinburgh Centre

The first meeting of the 1946/7 session was held on the 21st October, in the Blenheim Rooms, Mr. J. Atkinson, Area Engineer (Mtce.), giving an interesting lecture, the subject being "The A.B.C. of Impulsing." The remainder of our programme is as follows:—

January 20th. "The New Development Scheme." A. E. Jemmeson.

February 17th.—"Any Questions."

March 17th.—"Radio Communication." J. R. Hall and W. S. Ross.

April 21st.—"Annual general meeting."

The committee would like to take this opportunity to extend to all engineering staff in the Edinburgh Area a hearty welcome to the above meetings.

Membership and attendance are unsatisfactory, owing, it is believed, to the eligible staff not fully appreciating the benefits to be derived. Will the end of rehabilitation see our troubles over?

G. J. F.

Middlesbrough Centre

An interesting programme for the 1946/47 session has been arranged which includes two special items of interest to all, namely, a visit to the Dorman Long Britannia steel works and one to the North Teespower station.

At present the membership numbers 50, but it is hoped to increase that considerably in the near future. We appeal to all our staff to do all they can to bring in new members, particularly the younger ones, who we feel sure will derive great benefit from the different subjects discussed at the meetings. G. R. M.

North-Eastern Region Centres

The North-Eastern Region is following with great interest the activities of its junior centres, and the officers and committees are to be commended on getting together attractive programmes with the support of the North-Eastern and Northern Committees of the Senior Section. Some idea of the activities can be gained from the following brief notes.

Harrogate.—The centre has recently commenced activities for the winter session with 15 members. Meetings commenced on 28th November, and it is proposed to have two meetings per month. Members of the E-in-C's staff at Harrogate are giving co-operation.

Lincoln.—This is an active centre with 110 members, and a good winter programme has been arranged. Consideration is being given to constituting a separately financed Radio Sub Section. So far, during this session, 28 books have been borrowed from the Central Library by 18 different members.

Hull.—This section consists of 17 members. A small but varied programme has been worked out, and meetings are held jointly with Hull Corporation Telephone Society. Meetings are held once per month.

Leeds.—This centre has 84 members, of whom 10 are making use of the Central Library facilities, and has a full winter programme.

Doncaster.—There are 50 members and the programme for the winter session is being maintained.

Scarborough.—This centre commenced in 1938, with a membership of 30, and continued throughout the war with an average membership of 20. The present membership is 38, and active use is made of the Central Library. The Head Postmaster has placed a room in the H.P.O. at the disposal of the centre. An interesting visit was recently made to H.M.S. *Birmingham* while on a courtesy visit to the resort.

Grimsby.—This centre has opened its winter session with 19 members. The meetings have been arranged so as not to clash with evening classes, and it is hoped to maintain one meeting per month from November to March.

Halifax.—Interest in this junior section is being maintained. The centre has 43 members.

Regional Notes

North-Eastern Region

EXTENSION OF A PRE-2,000 TYPE SATELLITE EXCHANGE WITH THE 800-LINE SEMI-AUTO 2,000 TYPE EQUIPMENT

The use of the 800-line semi-auto 2,000 type equipment for extending a pre-2,000 type satellite exchange would in the majority of cases be straightforward, but the particular case at Roundhay (Leeds) presents problems which it is thought are of interest.

Roundhay exchange, with a numbering range of 61,000-64,999, had for some time catered for a "hypothetical" exchange for Moortown, with a numbering range of 65,000-66,999. This arrangement had been made possible by the teeing of second selector levels, as shown in Fig. 1.

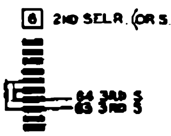


FIG. 1

The 66 and 65 numbers were allocated in the 63 and 64 final selector multiples, where the particular numbers were "spare," e.g. 65,111 was obtained via 64,111 final selector multiple, the number 64,111 thereby being deleted from the Roundhay "spare" numbers. The teeing was carried out on the D.S.R.'s at Roundhay and on second selectors at Leeds (main auto). Manual board outgoing jacks and 2 V.F. selector levels were similarly teed.

A contractor's extension of 1,600 multiple (65,000-66,599) having been scheduled for later installation, the Departmental "temporary" extension was required to keep within this numbering range. This extension was necessary to cater for the "waiting" subscribers and development forecasts up to the completion of the contract extension.

Some cutting of the second selector teed levels was therefore necessary. The most straightforward way would have been to provide the additional 800 lines in the 65 series by providing third selectors on the 65 group and using levels 0-7 with the 8-9 levels teed with existing 648-9 third selector levels to cater for the mixed 648/658, etc. numbers.

An examination of the numbers already allocated in the 64/650-7 hundreds revealed that the spare numbers in the 64 (Roundhay proper) and the 65 (Moortown hypothetical) groups were in proportion 6 : 2. Further examination of the levels in the 63/66 range revealed a reverse proportion. The "waiting list" of potential subscribers provided a 50/50 ratio which set the problem which prompts this article.

After various combinations had been considered the nearest scheme to an equal ratio was to take three levels from 65 and five levels from 66. The major items, racks, discriminating selectors, etc., had by this time arrived and work on the portions other than this third selector problem was progressing. Only one group selector rack having been provided, the shelves were split to provide two shelves of 10 selectors each in the 65 group, and three shelves of 10 selectors in the 66 group. Two shelves in the old exchange portion were rearranged to give an additional 20 selectors in the 65 group and 10 in the 66 group. Third selector levels 655-6-7 and 660-1-2-3-4, from both sets of third selectors, were graded to the 200 line final selectors which were arranged as 655/6, 657/660, 661/2 and 663/4. It was necessary to tee the remaining 12 third selector levels (7 on 65 and 5 on 66) with the corresponding 64 and 63 third selector levels in order to deal with the mixed numbers which had not been segregated, with a resulting trunking diagram as in Fig. 2.

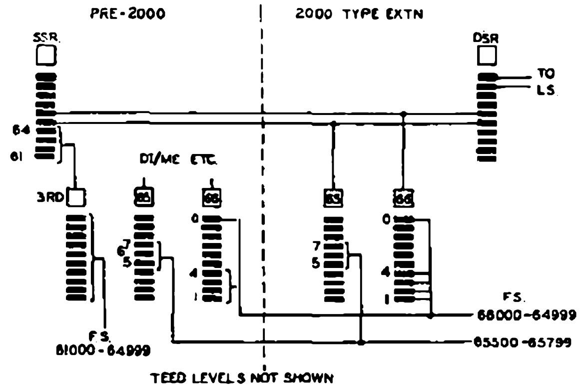


FIG. 2

Under this arrangement approximately 380 working lines were switched over to the new equipment at the moment of opening up the teed levels.

At another of the satellites (Chapeltown) a similar extension by the 800 line equipment is in progress, but in this case no problems of a like nature have been encountered.

South Western Region

LIGHTNING DAMAGE IN CORNWALL

During the morning of the 29th September, 1946, severe thunderstorms occurred over almost the whole of Cornwall, but caused little damage except at one exchange, St. Day, a U.A.X. 12, near the north coast. A lineman was working in the exchange at the time when a terrific explosion occurred, and all the power company's equipment was blown from the wall. All the fuses, both line and alarm, were blown in the exchange, and also many of the protectors at subs' premises in addition to the junction fuses at the parent exchange. Temporary service was given the same day on the junction route by utilising odd wires in the junction cable, and a few subscribers' services were also restored by temporary means. Service to the remaining subscribers had to await the renewal of many lengths of underground and aerial cable, and also block terminals on eight of the nine D.P.s. Although thunderstorms are very prevalent in Cornwall, it is unusual to have such severe damage localised in such a small area. C. P. I.

A NON-STANDARD MANHOLE

It does not often happen that a practical demonstration of how to build a manhole is given immediately outside a Telephone Manager's office, but this has happened recently in Gloucester. Due to this, it is perhaps safe to say that considerably more interest has been taken in manhole building by those not directly concerned than is usually the case ; in fact, one or two of the staff seemed to have appropriated the hole all to themselves. The manhole is of a non-standard type, built to relieve one which is congested, a few yards away. Placed in the centre of the road, very little was found by way of obstruction, although there were some signs of previous excavation having taken place, and the rumour did get round that a skeleton had been found.

Discussions on the various phases of the work were frequent. The relative merits of local sand and gravel as compared with other qualities was one subject which had a natural local bias, but the question which produced the most constructive comments was that concerning the advantages of the use of the standard reinforcing material over other types of roof support.

The drawing will give a good idea as to the actual work involved. Now that the job is completed, and traffic is again rolling over the spot, we feel that something is missing.

J. A. C.

Scottish Region

MR. JAMES McINTOSH

It is with deep regret that we have to report the sudden death, on 5th November, of Mr. James McIntosh, Telephone Manager of the Edinburgh Area. Mac, as he was affectionately known by his colleagues and friends, started his career as a telecommunications engineer in 1902 with the National Telephone Company. He served as a workman, and later as an Inspector, at Dundee and Inverness, and was promoted to Chief Inspector at Edinburgh in 1929. He remained in Edinburgh as Assistant Engineer, Area Engineer, and finally when he was appointed Telephone Manager in September, 1939.

Mr. McIntosh was a well-known figure in the Scottish telephone world, and was widely recognised throughout the country on account of his work on efficiency and organisation. His death is particularly sad, since he was due to retire at the end of the year, and was looking forward to a period of rest and security after a long and energetic official career. He is survived by his widow and three children.

J. A.

MONIGHAN DRAGLINE CROSSING TRUNK LINE

The "Monighan" 6W Dragline shown in the accompanying photograph was to be seen recently crossing the Fife countryside at the speed of one mile per day,

obstacles permitting. The "Monighan" is used in opencast coal mining, and excavates 3,000 tons of coal per week. It weighs 382 tons, is 43 ft. in width and 55 ft. in length. The top of the frame is 38 ft. above ground and the length of its jib is 150 ft.

In order that the machine could move across country to a new site it was necessary to divert underground all P.O. overhead plant in its path. The photograph shows it crossing the Edinburgh-Perth trunk route which carries a 4/40 + 208/20 pair aerial cable in addition to a number of heavy-gauge wires.

D. G. B.

OPENING OF CRAIGLOCKHART EXCHANGE

The opening of Craiglockhart exchange on 13th July, 1946, completed the first stage in the introduction of director working in the Edinburgh multi-office Area. The opening ceremony was attended by Mr. Penny, Vice-President of the Edinburgh Chamber of Commerce, and also the President of the Leith Chamber of Commerce. The first subscriber's line was cut over by Mr. Penny; 920 subscribers were successfully transferred to the new exchange, which is equipped with a 2,400 line bank multiple, and 2,260 subscribers' calling equipments.

The introduction of a director exchange in a Siemens 16 area has necessitated special arrangements to provide inter-dialling facilities. Battery dialling is normally used on incoming junctions at Siemens 16 exchanges, so that additional relay sets have had to be fitted at the Central exchange to convert the loop/disconnect impulses from Craiglockhart to battery impulses, and vice versa. Craiglockhart subscribers in dialling numbers on Siemens 16 exchanges precede the normal 5-digit number by the digits 21. The digits 21, together with the first digit of the subscriber's number, thus stepping the A digit selector and BC switch. The translation is 2 + first digit of the subscriber's number. Siemens 16 subscribers obtain access to subscribers on Craiglockhart by dialling the digits 70 followed by the four numericals of the Craiglockhart number.

D. G. B.

ABERDEEN RELIEF EXCHANGES

In common with other towns, Aberdeen has its waiting list, and although buildings were ready for an auto. conversion with the major part of the auto. equipment available, it became obvious that some relief measures would have to be adopted until such time as the auto. equipment could be brought into service.

The existing local C.B.1 suite served the whole of Aberdeen except the suburb of Woodside, which was served by a separate magneto exchange. The auto. scheme, however, provides for satellite exchanges in the North and West areas working into a central auto-manual exchange, and the fact that these buildings were already available has been of great assistance in meeting demands for service.

The provision of additional ducts and cable was necessary if the prospective new subscribers in the West and North areas were to be connected to the central manual board, and since this plant would be redundant on conversion to auto. it was decided to set up relief manual exchanges.

The first exchange provided is installed in the building designed for West satellite at Thorngrove Avenue. It consists of 4 C.B. No. 10 positions, a multiple of 1,120 lines, and a similar amount of calling equipments. The 24 V. power supply is derived from a 50 V. parallel battery float scheme, reduced by the insertion of suitable counter E.M.F. cells. Order wire working is used to the main exchange, and signal junctions in the reverse direction. As the "A" positions at the main exchange were fully loaded, it was necessary first to transfer 400 subscribers' circuits to West relief to free a position for conversion to i/c order wire working. To identify lines connected to West, the 400 transferred circuits and all new subscribers' connected have been given numbers within the proposed numbering range of West satellite. Actually only 20 numbers from each 100 group have been chosen to allow an equitable distribution over the final selector groups under auto. conditions.

The provision of a North manual relief exchange cannot be catered for in the auto. building, and a prefabricated building is to be erected for this purpose. In the meantime, the Woodside exchange which is proper to the North auto. satellite has had to be transferred to the central relief switchboard owing to termination of the lease for the Woodside premises.

The second central relief switchboard is located in Telephone House. Accommodation for this exchange was made available by the transfer of staff to rented premises, and it consists of 19 C.B. No. 10 positions arranged as follows :—

Positions	1 and 2	i/c order wire positions
,,	3	J.E.B. position
,,	4 and 5	Woodside
,,	6 to 18	"A" positions
,,	19	T. and P.U. position

Position No. 1 has not yet been brought into service. It is being held in reserve for working as an i/c order wire position from the sleeve control auto-manual switchboard which is being provided in advance of the main automatic installation to relieve the load on the existing trunk switchboard. The build-up of the relief exchange was done in stages. Initially traffic from the main suite was handled over signal junctions, and in the reverse direction by order wires teed temporarily to those i/c from West relief and handled by the same operator. The next stage involved clearing an "A" position in the main suite to provide i/c order wires from the central relief. This was accomplished by leaving the subscribers' multiple appearance on the main suite but transferring their "home" positions to the relief. Actually three positions have been cleared in this manner and converted to handle the i/c traffic from the relief exchange.

The relief exchange equipment comprises :—

(1) 280 calling equipments for Woodside, not multipled.

(2) 940 home appearances (jacks and lamps only) for transferred circuits with multiple appearance remaining on main suite.

(3) 1,900 calling equipments for new subscribers.

(4) 2,000 subscribers' multiple.

(5) 200 o/g junction multiples.

The apparatus room for the relief is self-contained and includes an I.D.F. of 21 verticals. Chargeable time clocks on the basis of 4 per position and meters for the relief exchange subscribers have been provided.

The arrangements and layout necessarily adopted will complicate the auto. transfer arrangements, but such difficulties are made to be overcome.

The time-table arranged for the work has been well maintained and credit to the installation staff is due for ironing out the many snags encountered on a not so straightforward job.

W. C. McD.

Welsh and Border Counties Region

NEVIN-HOWTH CARRIER SYSTEM CONVERSION TO 24-CHANNEL WORKING

On Sunday, 22nd September, 1946, the Nevin-Howth 12-channel carrier system, which carries the telephone traffic from this country to Dublin, was converted to 24-channel operation.

The original equipment consisted of one 12-channel group using a G.E.C. No. 6 carrier terminal controlled locally by 1 kc/s fork type master oscillators. By the loss of channel 1 in the 12-channel group a 1 + 4 carrier system was added and by this means 16 circuits were provided, one channel being used for a London-Dublin 18-channel V.F. telegraph circuit.

The initial and additional 12-channel groups are combined by high and low pass filters and are worked 4-wire over two concentric submarine cables. Arrangements for the emergency operation of half the circuits over either of the cables is provided.

The new system consists of two G.E.C. No. 7 12-channel groups, combined into a 24-channel group, controlled by the existing master oscillator. Owing to cable attenuation over the frequency range 12-108 kc/s the group has been pre-equalised and transmission is via a 10-watt power amplifier. On the receive side, two equalisers and two No. 7 type line amplifiers are worked in tandem to provide the required input to the group and channel equipment.

Below the 24-channel group the audio circuit and bottom two channels of the 1 + 4 carrier system have been added, and the result of the conversion is that 27 circuits are now available. Two of the channels carry 18-channel V.F. telegraph circuits. A switching panel allows the 1 + 4 system to be operated on one cable to enable a music circuit to be worked on the second cable.

The work was planned, tested and lined up by the Engineer-in-Chief's Office, Lines Branch. A considerable amount of preparatory work on circuit rearrangements was carried out by local staff in the Chester Telephone Manager's area, and this assisted materially in reducing lost traffic time to a minimum during the conversion.

N. G.

DAMAGE TO NEATH POWER STATION, 22nd SEPTEMBER, 1946

Gales of 60 m.p.h., floods and magnetic storms are not unusual in this country, but when they all occur simultaneously with the destruction by fire of a municipal power station, the events are perhaps worth recording.

One indirect result of the bursting of the banks of the River Neath at Neath, Glam., during the height of the storms of 20th to 23rd September, 1946, when 15 exchanges were isolated, and about 1,000 subscribers' lines were put out of order in the Swansea Telephone Area, was a fire which seriously damaged Neath power station.

The fire occurred at about 8 p.m. on Sunday, 22nd September, when the station, with an output of 20,000 kW, serving a population of 60,000 in Neath, Briton Ferry and Skewen, failed, due to the burn-out of a large transformer following the non-operation of an overload trip coil. The blazing oil from the transformer spread very quickly, and the attendant, who was located in a gallery cabin, was extremely lucky to escape with his life.

Unfortunately, the telephone was located in the attendant's cabin, and he, in his excitement, had failed to notify the Fire Brigade. It was impossible for him to return through the burning oil, and although he incurred minor injuries, he pluckily ran over half a mile to the nearest telephone to warn the brigade. By the time they arrived serious damage had been caused, and it was obvious to the local Post Office Inspector, who was soon on the scene, that arrangements would have to be made to bring emergency battery charging equipment into operation without delay.

Three exchanges, Neath manual with 800 subscribers, Skewen manual with 200 and Briton Ferry U.A.X. with 200 subscribers, depend on Neath power station for their power supplies, and it was imperative, particularly so at Neath, that the batteries should be on charge by mid-afternoon on Monday, 23rd September.

The emergency organisation was put into operation, and by mid-day Skewen manual exchange batteries were on charge, Neath following at 2.15 p.m. As soon as possible after the charging commenced, the 600 non-essential subscribers' lines, which since Sunday midnight had been subject to emergency control procedure, were restored to normal working. Briton Ferry U.A.X. batteries were on charge by 4.30 p.m., but Neath Post Office, which is located at some distance from the exchange, was still without light and power, because the charging set which had been towed from Carmarthen, 40 miles away, was giving engine trouble. However, by 10.30 p.m. the engine was running well enough to supply light and power, and Neath Post Office was soon functioning normally.

The emergency sets were in use until 7 p.m. on Wednesday, 25th September, when temporary repairs enabled the station to take the load.

N. C. de J.

AN EXPERIMENTAL U.A.X. COMMON EQUIPMENT TESTER

The reconditioning of U.A.X. time-pulse, tone and ringing relay-sets at overhaul centres has emphasised the need for a tester for this type of equipment. It is essential that apparatus which has been overhauled should be despatched with the certainty that it will function correctly when brought into use at the U.A.X.

A complete overhaul may include the changing of a uniselector bank, with the consequent danger of wiring reversals. This may affect one or other of the various functions of the apparatus, which, without a suitable tester, can be checked only when restored to service in the U.A.X.

A circuit for a tester was developed in the Regional Engineering Branch and was constructed from recovered apparatus. Wiring was carried out at Newport (Mon.) automatic exchange and several useful circuit modifications suggested by the local staff were incorporated.

Ringing and meter pulse and tone and time pulse sets for U.A.X. 12 and 13 are tested to prove all functions and a recent addition to the circuit allows for the testing of equipment to which retrospective changes have not been applied.

The operation of keys enables each facility to be tested separately. Repeat tests can be made quickly and conveniently at the bench and the tester has proved to be a very satisfactory aid to the overhaul staff.

S. E. N.
H. L.

Staff Changes

Promotions

Name	Region	Date
A.S.E. to Staff Engr.		
Hanford, S.	E.-in-C.O.	1.11.46
Exec. Engr. to A.S.E.		
Barker, P. L.	W. & B.C. Reg. to N. Ire. Reg.	13.10.46
Dunford, L. G.	Test Section, London	1.11.46
Longmore, F. W.	E.-in-C.O. to W. & B.C. Reg.	15.9.46
Carter, R. O.	E.-in-C.O.	13.9.46
Jones, R. E.	L.T.R. to E.-in-C.O.	16.10.46
Asst. Engr. to Exec. Engr.		
Whittaker, A. W.	L.T.R.	19.9.46
Young, J. S.	E.-in-C.O.	20.9.46
Edwards, W. K.*	Scot. Reg.	19.9.46
Thomas, G. E. T.	L.T.R.	19.9.46
Gill, W. E.*	Scot. Reg.	19.9.46
Neate, A. D.	H.C. Reg. to L.T.R.	19.9.46
Hunt, A. M.*	N.E. Reg.	19.9.46
Atherton, W. S.	E.-in-C.O.	19.9.46
Weaver, E. W.*	S.W. Reg.	19.9.46
Beaumont, E. B. M.*	L.T.R.	19.9.46
Dunn, W. K.*	L.T.R.	19.9.46
Prescott, J.*	E.-in-C.O.	19.9.46
Lillicrap, H. G.	E.-in-C.O.	19.9.46
Hibbs, N. L.	L.T.R.	19.9.46
Hanman, B. L. G.	E.-in-C.O.	19.9.46
Chief Insp. to Asst. Engr.		
Jones, C. E.	Mid. Reg.	22.9.46
Stevens, F. W.	S.W. Reg.	3.9.46
Slater, G. H.	E.-in-C.O.	3.9.46
Smith, C. A.	L.T.R.	22.9.46
Jones, E. T.	L.T.R.	22.9.46
Ellis, W.	N.E. Reg.	3.9.46
Chief Insp. to Asst. Engr.—continued		
Pemberton, W. J.	E.-in-C.O. to S.W. Reg.	22.9.46
Cleary, C. L.	N.W. Reg. to S.W. Reg.	22.9.46
Beniston, S.*	Scot. Reg.	3.9.46
Walters, J. R.	E.-in-C.O.	3.9.46
Walker, A. H.	L.T.R.	1.10.46
Ibbett, R. E.*	H.C. Reg.	30.9.46
Marshman, R. C.	E.-in-C.O.	3.9.46
Loughlin, J. J.	Scot. Reg.	30.9.46
Allan, A. F. G.	E.-in-C.O.	1.10.46
Blott, F.	L.T.R.	7.10.46
Deighton, C. F.	N.E. Reg.	6.11.46
Inspr. to Chief Inspr.		
Carter, G. W.	H.C. Reg.	18.8.46
Barron, D. J. F.	L.P. Reg.	1.7.46
Jones, G. A. H.	H.C. Reg.	26.7.46
Moffatt, J. J.	E.-in-C.O.	22.9.46
Anthistle, A. W.	Mid. Reg.	26.5.46
Southwell, C. E.	N.E. Reg.	18.1.46
Whitting, W. G.	S.W. Reg.	26.8.46
Henson, F. B.	Mid. Reg.	22.9.46
Mainwaring, G.	Mid. Reg.	25.8.46
Smith, L.	Mid. Reg.	24.3.46
Richards, P. W.	Mid. Reg.	25.7.46
Hawarth, J.	N.W. Reg.	9.5.46
Harris, R. V.	L.T.R.	11.3.46
Arthur, J. C. C.	L.T.R.	27.12.45
Kent, S. T. E.*	L.T.R.	23.9.46
Alexander, G. E.	L.T.R.	23.9.46
Milton, A. G.	L.T.R.	11.10.46
Baxter, E. C.	L.T.R.	7.3.46
Smith, J. R. G.	L.T.R.	12.10.46
Fuller, W.	L.T.R.	29.7.46
Smith, F. J.*	L.T.R.	13.10.46
Wooding, W. J.	L.T.R.	13.10.46

* In absentia.

Retirements

Name	Region	Date
Staff Engr.		
Barralet, F. O.	E.-in-C.O.	31.10.46
Asst. Staff Engr.		
Plymen, H. S.	E.-in-C.O.	30.9.46
Exec. Engr.		
McGregor, J. E. M.	E.-in-C.O.	31.8.46
Wood, G. E.	L.T.R.	31.8.46
Asst. Engr.		
Bryant, G. H.	H.C. Reg.	18.11.46
Hogbin, A.	E.-in-C.O. (Resigned)	6.10.46
Haigh, H. L.	N.E. Reg.	31.8.46
Varrall, J. E.	E.-in-C.O. (Resigned)	31.10.46
Boys, E. C.	L.T.R.	30.9.46
Chief Insp.		
Burt, J. E. G.	S.W. Reg.	31.10.46
Ellis, F. G.	L.P. Reg.	29.10.46
Soons, A. T.	E.-in-C.O.	31.8.46
Town, A.	L.T.R.	28.10.46
Inspr.		
Doughty, E. M.	L.T.R.	1.11.46
Maggs, C. W.	L.T.R.	30.9.46
McCullough, J.	Scot. Reg.	26.11.46
Crofts, A. A.	E.-in-C.O.	17.11.46
Beech, W. H.	L.T.R.	8.11.46
Wonson, J. F.	E.-in-C.O. (Resigned)	16.9.46
Morley, G.	L.T.R.	31.10.46
Whyte, D. B.	Scot. Reg.	25.9.46
Ridler, G. H.	E.-in-C.O. (Resigned)	30.9.46

Deaths

Name	Region	Date
Exec. Engr.		
Wilson, F.	E.-in-C.O. (Criggion)	3.10.46
Chief Inspr.		
Davies, H. S.	W. & B.C. Reg.	16.9.46
Inspr.		
Mason, H.	Mid. Reg.	1.11.46
Clevely, S. E.	E.-in-C.O.	20.11.46

Transfers

Name	Region	Date	Name	Region	Date
Regl. Engr.			*Chief Inspr.*		
Hines, R. J. ..	.. Mid. Reg. (Mobilised) to N.E. Reg.	9.9.46	Hicks, C. J. ..	.. N. Ire. Reg. to L.P. Reg.	1.11.46
Exec. Engr.			Wilson, L. P.	.. E.-in-C.O. to Overseer, Factories Dept.	25.11.46
Parsons, R. A. E.	.. E.-in-C.O. (Mobilised) to L.T.R.	7.10.46	Bolus, E. H. ..	.. N. Ire. Reg. to L.T.R.	17.11.46
Gleadle-Richards, E. M.	E.-in-C.O. to L.T.R. ..	1.9.46	*Inspr.*		
Brett, S. I. ..	.. L.P. Reg. to E.-in-C.O.	1.9.46	Ingram, C. S.	.. R.S. (Leafield) to E.-in-C.O.	1.11.46
Mead, F. C. ..	.. N.W. Reg. to E.-in-C.O. (with £100 allowance)	1.11.46	Stears, A. D. S.	.. R.S. (Edinburgh) to Scot. Reg.	16.11.46
Leckenby, A. J.	.. E.-in-C.O. (Mobilised) to L.T.R.	28.10.46	Horne, F. A. ..	.. Scot. Reg. to E.-in-C.O.	10.11.46
			Pritchett, J. ..	.. N.W. Reg. to E.-in-C.O.	5.10.46
Asst. Engr.			Hamer, R. ..	.. W. & B.C. Reg. to E.-in-C.O.	23.9.46
Annan, L. T.	.. E.-in-C.O. (Mobilised) to L.T.R.	11.11.46	Elkins, N. A.	.. N.E. Reg. to E.-in-C.O.	16.9.46
			Knight, L. C.	.. L.T.R. to E.-in-C.O. ..	11.9.46
Roy, D. W. ..	.. E.-in-C.O. to L.P. Reg.	1.9.46	Roberts, G. H.	.. Test Section to E.-in-C.O.	2.9.46
Trussler, H. ..	.. L.T.R. to S.W. Reg. ..	1.9.46			
Edwards, A. G.	.. E.-in-C.O. to H.C. Reg.	24.11.46	Braddick, H. A.	.. L.T.R. to E.-in-C.O. ..	3.10.46

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MODEL ANSWERS

TO

CITY AND GUILDS OF LONDON INSTITUTE EXAMINATIONS

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The questions and answers which have appeared in the Supplement to the Post Office Electrical Engineers' Journal are being regrouped according to the syllabuses of the revised examinations and will be published in book form. The following books have been prepared and will be published shortly.

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Price 2/6 (post free 2/9)

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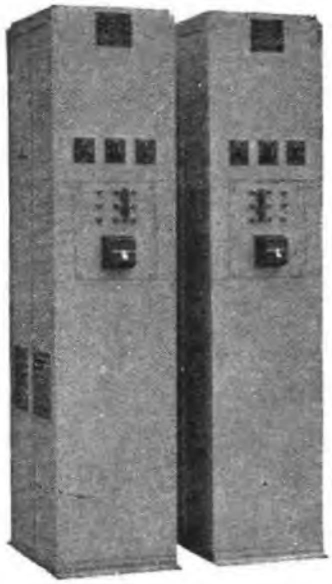

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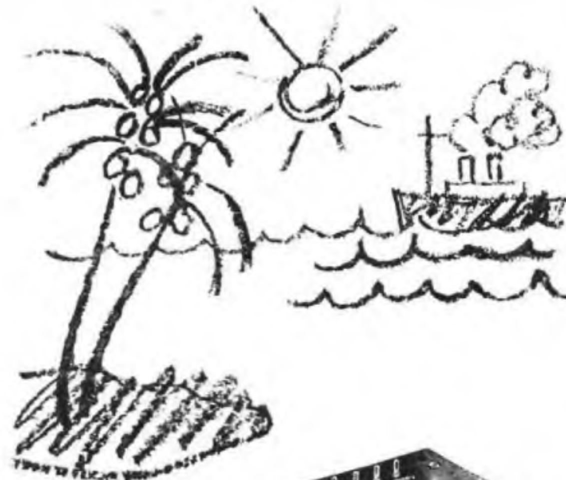

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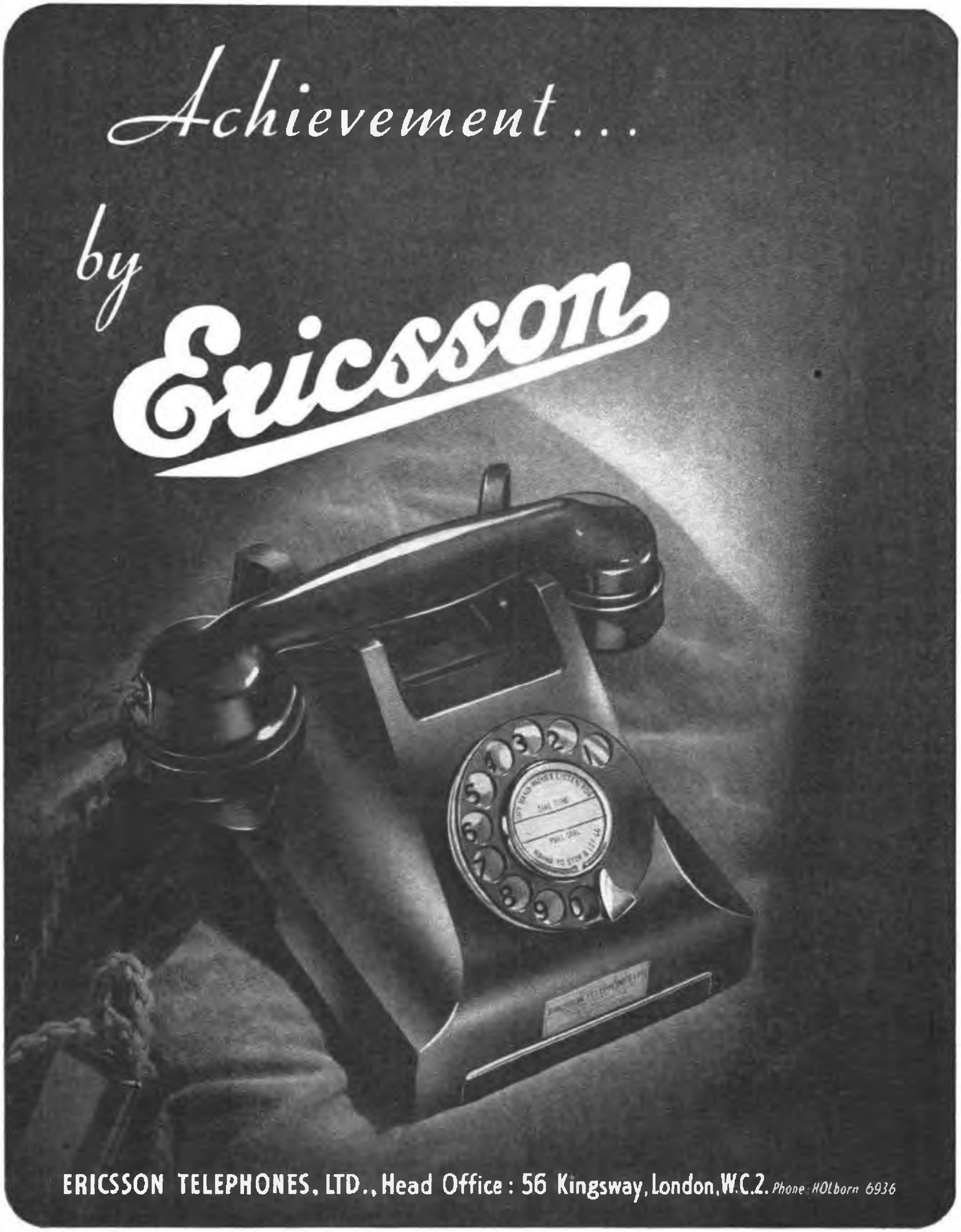
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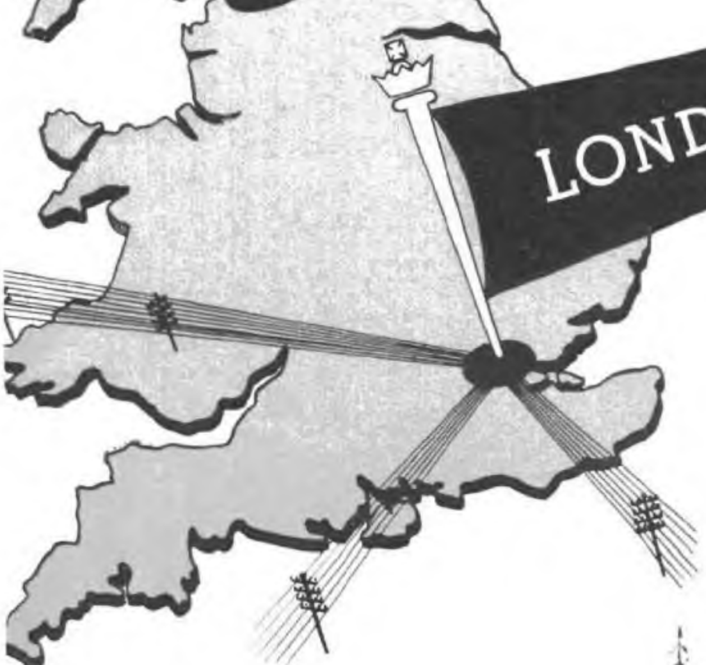

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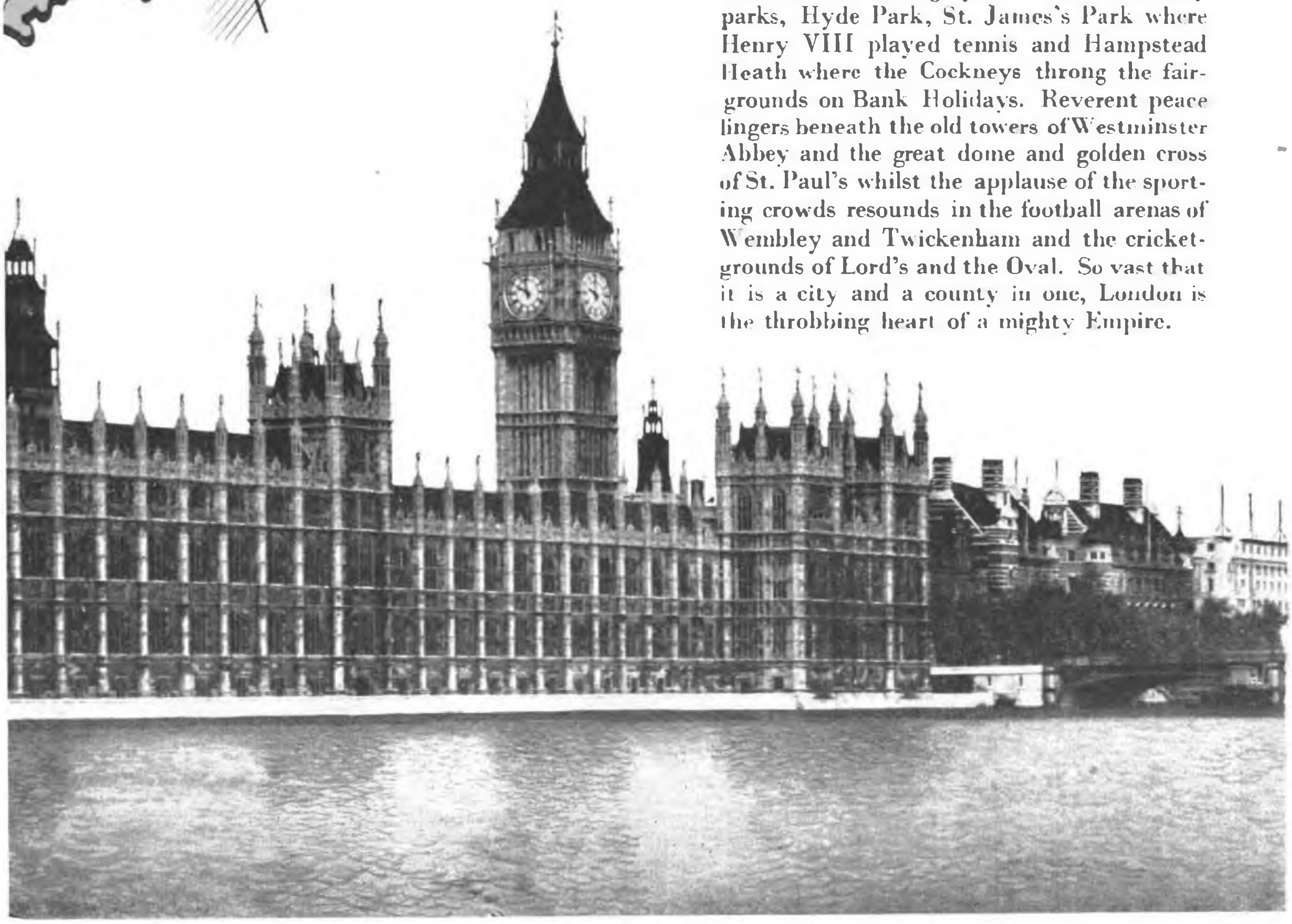

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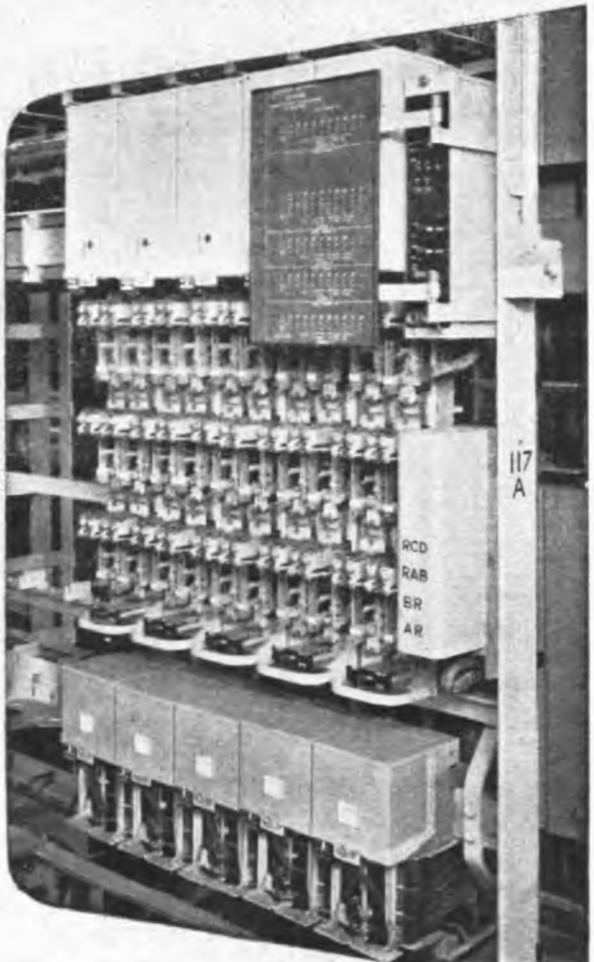

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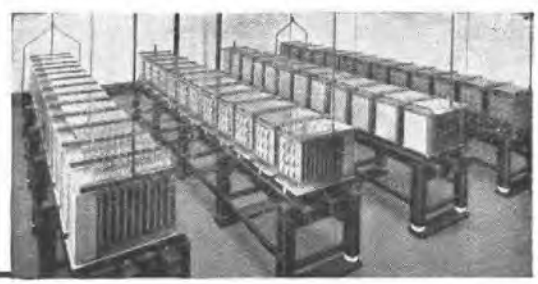

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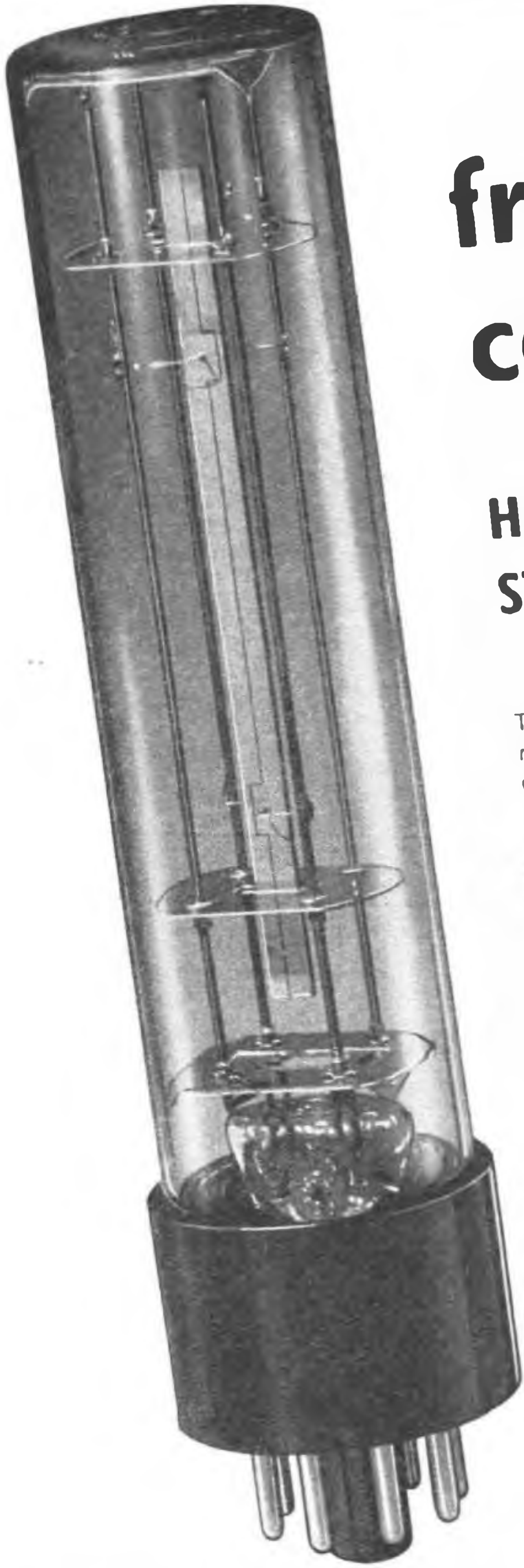

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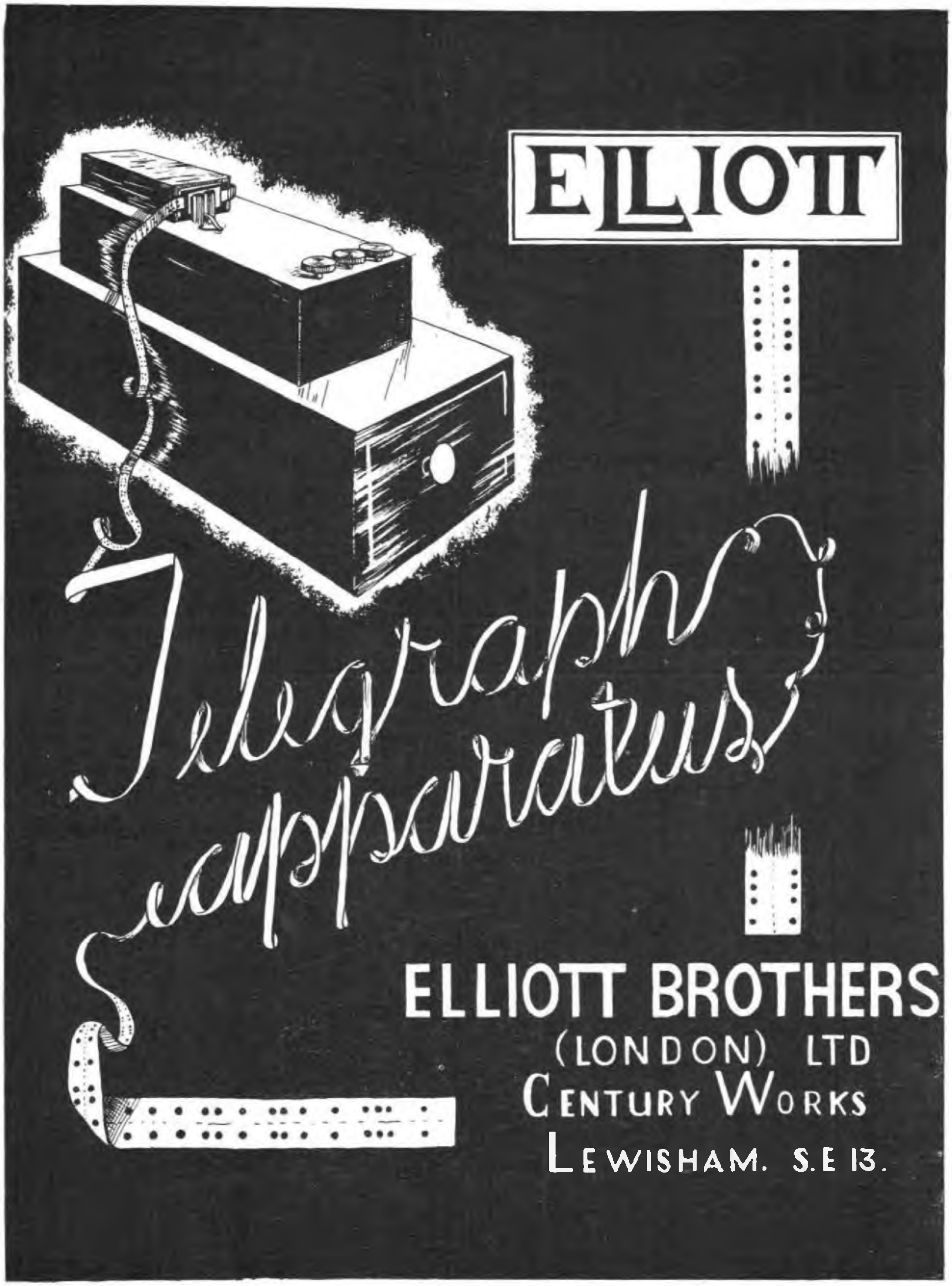
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