current of 2·5 micro-amperes is considered necessary for reliable communication.

Under field service conditions, the range called for would not normally exceed 15–20 miles and only the most severe interference from stray earth currents would interrupt communication.

4. *Constructional details* (*see* Plates I, II, III, IV and V).—The Fullerphone is housed in an aluminium case which, in turn, slides on guides in a wooden carrying case provided with a sling. The headphones are held in the lid of the carrying case. A spring stop which holds the unit in position in the carrying case is pressed down for the unit to be drawn forward into the operating position. A second stop prevents the unit from sliding completely out of the case and a leather pad on the left-hand side of the case presses on the instrument and holds it firmly in place. When in the operating position, the outer case gives some measure of protection to the instrument when working in bad weather. The unit may be withdrawn completely from the carrying case by again pressing the spring stop and drawing the unit forward, when the batteries and buzzer-chopper may be removed. The batteries are accessible by lifting the small lid on the left-hand side of the instrument, the buzzer battery being at the rear.

The buzzer-chopper (Buzzers F, Mk. II—*see* Plates II, IV and V) unit slides into position on the top right-hand side of the instrument, the connections being made by contact springs. The morse key is mounted at the bottom right-hand side of the unit. All the other components are contained in the aluminium case.

The instrument control panel is of aluminium and carries the line terminals L_1 and L_2, potentiometer control knob, reversing switch (marked A–B), "PULL-ON" switch and two "PHONE" sockets.

2. Technical Description

1. *The circuit.*—The theory of operation of the circuit is fundamentally the same as that described in Signal Training, Volume II, Part III, 1936, Sec. 44. In the Fullerphone, Mark IV, circuit (*see* Fig. 1), however, one dry cell B_1 is used to operate the buzzer-chopper and supply the sending current.

A potentiometer R, dry cell B_2, and reversing switch S_2 (marked A–B) are also provided, so that stray earth currents or leakage currents from other circuits may be balanced out. A pull-on switch S_1 connects the battery B_1 to the buzzer-chopper and also the balancing battery B_2 to the potentiometer

circuit via the reversing switch. When the reversing switch is set to "A" or "B" positions a potential (identical but reversed in the "B" position) is put in series with the line, the exact potential being dependent upon the setting of the potentiometer. When the reversing switch is in the centre position, the potentiometer is removed from the line and the battery B_2 circuit is broken.

Two headphone jacks J_1 and J_2 in parallel enable a number of Fullerphones to be bunched together so that one operator can keep watch on more than one Fullerphone circuit during quiet periods (*see* Working Instructions, Sec. **3**).

2. *Line circuits.*—The line circuits over which the Fullerphone may be worked are described briefly below :—

i. *A twin line or a single line and earth return.*—The connections for this simple circuit are shown in Fig. 2, either a twin line or a single line and an earth return being used. The single line and earth return is liable to the various forms of interference from earth currents (*see* para. 3, below).

ii. *Simple series superposing.*—In the circuit, shown in Fig. 3, a telephone set and a Fullerphone are connected in series across each end of the line. The telephone sets must have D.C. paths between their terminals, and for this reason the circuit will not operate with the Telephone Sets F, Mk. I, which has no D.C. conducting path when the handset is on the cradle.

Fullerphone working is possible, however, through the Telephone Sets D, Mk. V, which presents a resistance of about 1,000 ohms to D.C. currents.

The network of chokes and condensers in the Fullerphone circuit prevents any sudden rise or fall of current and, consequently, no clicks are heard in the telephone instrument from Fullerphone signals.

Simple series superposing may also be carried out between a telephone exchange and a telephone set or between two telephone exchanges providing they each present a D.C. conducting path at all times. Connections are made to a pair of line terminals on the switchboard instead of to the terminals of a telephone set.

NOTE.—If the circuit of Fig. 3 is connected through an exchange to a similar circuit, four superposed Fullerphones will be connected in parallel on the same line and will interfere with each other.

iii. *Series superposing with the Superposing Units (One Transformer).*—In this circuit, shown in Fig. 4, the Fullerphone is connected between the two halves of the secondary of the superposing transformer. This form of circuit enables series

superposing to be carried out on lines connected to telephone sets, such as the Telephone Sets F, Mk. I, which has no D.C. conducting path when the handset is on the cradle.

iv. *Superposing phantom circuits using the Superposing Units (One Transformer).*

Some of the more usual circuits are shown in Figs. 5–9.

The circuits of Figs. 5 and 6 may be used when phantom superposing is required on one or two twin lines. No interference from magneto generator or buzzer signals is experienced with either of these circuits, while with the circuit of Fig. 6 interference from earth currents is avoided.

Fig. 7 is a development of the superposing phantom method which is sometimes required, while Figs. 8 and 9 show circuits for an intermediate Fullerphone station superposed on one or two twin lines.

The circuits shown in Figs. 4 to 9 are fully described in the Pamphlet No. 20, "Superposing Units (One Transformer)" of this series. The Superposing Units (One Transformer) fulfils the same functions as a repeating coil (*see* Signal Training, Volume II, Part III, 1936, Sec. 43).

3. *Interference.*—Fullerphone circuits are liable to various forms of interference :—

i. From D.C. earth currents, which are nearly always constant in magnitude.

ii. From A.C. earth currents of frequencies below 90 c/s which can pass through the filter circuit. These may be due to leakage from power supply mains or may be produced by an enemy to cause interference.

iii. From buzzer signalling currents caused when the Fullerphone is superposed in series on a circuit which utilizes a buzzer. In this case a click will be heard whenever the buzzer starts or stops.

iv. From magneto signalling currents caused when the Fullerphone is superposed in series on a circuit which utilises a magneto generator.

v. From electrolytic action taking place in cables which have lain in water for some time. This causes a form of interference which is generally rather variable in magnitude and difficult to balance out. The only remedy is to lay a new cable.

In general, A.C. earth currents do not cause very serious interference. They can be recognised because the potentiometer for balancing out D.C. earth currents has no effect on A.C. interference.

Difficulties in working the Fullerphone are almost invariably due to interference from small currents being picked up by the line, either by the earth, by earth faults or leakage from other circuits. The current to cause the disturbance must be of a steady nature or of a low frequency, since the output circuit of the Fullerphone will only pass D.C., and A.C. of any frequency below 90 c/s.

High-frequency currents (such as are produced by a buzzer or speech) induced in the line do not affect the working of the Fullerphone.

The effect of steady current interference is to produce a note in the Fullerphone of exactly the same pitch as the received signals, which are thereby confused and may be rendered unreadable. This disturbance may be balanced out with the potentiometer.

4. *The buzzer-chopper* (*Buzzers F, Mk. II*).—The Buzzer F, Mk. II, is a modification of the buzzer described in Signal Training, Vol. II, Part III, 1936, Sec. 14. It is a polarized buzzer operating from one dry cell only and uses one pair of contacts for " driving," the second pair being used for interrupting or " chopping " the D.C. signal pulses of the Fullerphone at approximately 550 times a second.

The particular electrical and constructional features of the Buzzer F, Mk. II (Plate IV and Fig. 1) which contribute to the efficiency of the instrument are as follows :—

i. The buzzer has a single winding wound on two bobbins.

ii. The armature returns to the initial position by spring action similar to that of an ordinary D.C. electric bell.

iii. Only one pair of contacts are used for " driving."

iv. High permeability iron is used for the yokes, pole pieces, armature, etc.

v. Polarising magnets of high coercivity are used which are little affected by shocks.

vi. Totally enclosed construction.

vii. The metals employed for the magnetic circuits are virtually non-corroding.

viii. Ease of adjustment, and stability of the adjustments when made.

ix. The ability to withdraw the buzzer complete from the instrument without disturbing any connections.

The iron circuit of the Buzzer F, Mk. II (*see* Plate V) consists of a yoke carrying two pole pieces for the bobbins, two flat polarizing magnets forming side pieces and an armature

carrying plate. The magnets are 15% cobalt steel of high coercivity, and the remainder of a special high permeability iron known as " Radiometal ". The armature, also of " Radiometal ", is attached to the armature carrying plate by a flat transverse spring about which it oscillates, the natural period of oscillation being about 350 c/s.

The contacts at each end of the armature are of platinum and are carried on small flat steel springs screwed to the armature. To the top of the armature carrying plate is screwed a moulding which carries the split bushes of brass for the fine thread contact screws. The locking knobs and the split bushes form collets which effectively lock the contact screws without altering their adjustment.

The three external connections are brought out to contact strips on the back plate of the buzzer. This back plate and the front cover plate are made of bakelized cambric.

The current consumption of the Buzzer F, Mk. II, when in the Fullerphone, and correctly adjusted with both contacts in operation, is approximately 1 mA.

3. Working Instructions

1. *Preliminary.*—

i. Unfasten the catches at the sides of the carrying case and fold back the lid.

ii. Press the spring stop in the centre of the base of the carrying case and keeping it depressed draw the instrument forward and out of the case.

iii. See that the cells in the battery compartment are in good condition and making good contact with their connectors.

iv. Push the unit back into the carrying case as far as the first catch—this is the normal working position.

v. Remove the headphones from the clips in the lid and plug them into one of the sockets marked " PHONES ".

vi. Join the terminals L_1 and L_2 by a short piece of wire.

vii. Pull outwards the knob marked " PULL-ON ".

viii. Depress the morse key and if a clear note is not heard in the headphones adjust the buzzer-chopper (Buzzer F, Mk. II) as follows :—

(*a*) Unlock the two knobs marked " BUZZER " and " CHOPPER," turning the locking rings anticlockwise.