shown in Fig. 8, when the interrupter contact X is making connection. When the circuit is closed at X, a current flows from the battery to E, through the distant station and back to Line terminal, through the secondary choke, coils, receivers, and No. 2 contact of the interrupter to the negative of the battery. At the same time the condensers become charged up to the voltage of the battery. When the circuit is broken at X, no current can flow from the battery. The condensers, however, are now able to discharge, sending a current to line in the same direction as the battery. The action of the choke coils and condensers maintains a steady flow of current to line as long as the key is pressed even though the battery circuit is being continually interrupted at contact X.

5. The result of the above arrangement is that the current from the sending battery, passing through the sending operator's receiver, enables him to hear his own buzzer signals, and to judge the strength of signals going to line. In addition, should the line be cut or the distant operator's chopper screw go out of adjustment, he is immediately notified by hearing musical clicks instead of his own buzzer signals. Should his own interrupter go out of adjustment, he will hear nothing at all.

6. The signals are much clearer than those from a " buzzer," as the commencement and end of a signal does not depend on the starting and stopping of a vibrating armature, hence the rate of working is higher than with a buzzer—always assuming that the operator is sufficiently skilled.

7. The arrangements of choking coils and condensers not only prevents any appreciable variation in the line current, but prevents any vibrating currents (such as are produced by induction from other circuits, by a buzzer on the line, or from a telephone) from passing through the operator's head telephones. All such currents pass through the condenser K1. Should any vibrating current make its way through Ch1 it will then take the path to earth through K2 rather than through the high inductance Ch2, thus the telephones are doubly protected from induced currents or from telephone currents passing over the same line.

8. When the sending battery is connected as shown in Fig. 8 the current can only rise in the line comparatively slowly owing to the effect of the capacity of the condensers and the self induction of the choke coils. The object of this retardation of the rise of current is to prevent clicks being heard in a telephone receiver inserted in the line. This has a two-fold object :—

(*a*) To prevent the possibility of Morse messages being read from these clicks.

(*b*) To prevent the clicks interfering with telephony carried on over the line simultaneously with Morse signalling.

It will be noticed that the Fullerphone is not a polarised instrument, and that the direction of the received current does not affect the signals.

4. *Superimposing Fullerphone and Telephone.*

Fullerphones, Mark III* may be superimposed on telephone circuits by means of Bridging Coils or Transformers in the usual manner, provided that the lines are balanced.

5. *Calling Arrangements with Fullerphone.*

1. In the Mark III* Fullerphones an arrangement has been made to send a strong buzzing current to line for purposes of calling attention. The interrupter buzzer is used for this purpose, and its ordinary battery is reinforced by two additional cells, making three in all. This call is considerably louder than the Fullerphone signals if the line is comparatively short and in reasonable condition, but if the line is of very high resistance or capacity the Fullerphone signals will be louder than the buzzer signals.

2. The buzzing call can be relied on in normal conditions, but if the circuit is very bad it may be possible to call and send messages on the Fullerphone when the buzzing call will not get through. In such cases it is necessary to call with the Morse key and to listen in, at short intervals, on the Fullerphone to ascertain if the station is being called.

3. It must be remembered that the buzzing call has all the disadvantages of the buzzer and, consequently, must never be used near the front line for sending any call or signal which it is important that the enemy should not overhear.

4. The Mark III* Fullerphone has at least as good a buzzer call as the " D " III telephone, and will thus work to buzzer switchboards in a similar manner and over similar lines.

6. *Disturbance due to Earth Currents or Leakage.*

1. Difficulties in working the Fullerphone are almost invariably due to small currents being picked up by the line either by the earths, by earth faults, or by leakage from Morse circuits. The currents to cause this disturbance must be of a steady nature, or of a low frequency. High frequency currents (such as are produced by a buzzer or telephone speech) or disturbances induced on the line do not affect the working of the Fullerphone. The effect of the steady current is to produce a note in the Fullerphone receiver of exactly the same pitch as the received signals, which are thereby confused and may be rendered unreadable. This disturbance can only be noticed when the local buzzer is running.

2. Disturbances due to induction will affect the telephone if such is incorporated in the Fullerphone, in the same way that they will interfere with any other telephone.

7. *Earth Currents.*

1. An earth current on the line causes a continuous hum in the Fullerphone receiver when the local interrupter is running. If the earth current is in the *opposite* direction to the signalling current sent out by the sending station, the signal received when the sending key is depressed will be that due to the difference between the sending and earth currents, while the sound when the key is not depressed will be that due to the earth current only. Hence, if the received earth current is half the received signalling current, the current will be altered in direction but not in magnitude, when the sending key is depressed and no signals at all will be received. If the earth current is greater than half the signalling current the signals will actually be reversed. If the currents are equal there will be silence at the receiving end when the key is depressed at the sending end.

2. If, on the other hand, the currents be in the *same* direction, the signalling current will always increase the earth current, and the signals will always give a louder note than the earth current alone.

3. If the received earth current be half the received signalling current, the result will be an increase in current in the proportion of 1 to 3 when a signal is being sent, which will frequently be readable. Hence the disturbance due to steady earth currents in a direction opposite to that of the signalling current can always be reduced (in most cases sufficiently to work the line) by reversing line and earth at the sending end, thus bringing both currents in the same direction.

4. The increase of sound due to an increase of current through the receiver does not depend merely on the magnitude of the increase or even of the relative increase, but the weaker the current the greater the audible effect of a given increase, or even of a given relative increase. Hence, if the current gives a loud note the signalling can be improved by increasing the resistance of the circuit, which is easiest done by *increasing* the resistance of the earth. *A good earth is not required* for the Fullerphone and is frequently a disadvantage.

8. *Use of the Potentiometer.*

1. The disturbance from a steady earth current from either a leak or from the earth pins can always be eliminated by the insertion of a potentiometer in the line at the receiving end and such a potentiometer forms a component part of the Mark III* instrument. The potentiometer consists of a length of high resistance conductor, through which flows a current from one cell. One end of this conductor is connected to one terminal of the potentiometer, and a sliding contact (which can be adjusted to make contact with any portion of the conductor) is connected to the other. The potentiometer is connected in series in the line and impresses a portion of the

E.M.F. of the cell on the line. If the E.M.F. thus impressed on the line is equal and opposite to that producing the earth current, the earth current and its disturbances are eliminated. To use the potentiometer put switch B, Figs. 1,3, 4, 5—L to position 1 or 2 and turn the handle, Figs. 1, 3, 4, 5—M, until the noise due to the earth current ceases. If it is found that the noise is increased (more or less) in every position of the handle, the potentiometer reversing switch, B, must be placed in the alternative position, when a position should be found which will give the desired result.

2. Each station must adjust its own potentiometer to suit the earth currents received by it. As the currents are frequently picked up at earth faults they will not necessarily be the same at each end of the line.

9. *Leakage Currents from Morse.*

1. A leakage current from a single-current Morse set will cause the signal from such set to be heard in the Fullerphone receiver when the interrupter is running. A similar current from a double-current set or duplex will give confused signals. In either case they may be strong enough to interfere with the Fullerphone signals.

2. If such currents leak on to the Fullerphone circuit at a contact on the line, the only thing is to clear the contact.

3. Such leakage, however, frequently occurs at the office, either owing to leakage at the test board, or commutator, or at the earths.

4. *The same earth should not be used for both Fullerphone and Morse circuits,* or interference is almost certain to result. The best earth obtainable should be used for the Morse, and an inferior earth used for the Fullerphone. The earths should be as far apart as possible and the wires leading to them should be kept clear.

5. A bad earth will not be disadvantageous for the Fullerphone proper, unless very bad indeed, but the speaking (if such is required) may suffer.

6. If there are Morse and Fullerphone instruments in the same office the circuits and their earths should be kept entirely separate.

7. It must be remembered that the Fullerphone is very sensitive and that 1/1000th part of the current usually employed in Morse working will give strong signals in the Fullerphone.

10. *Explanation of Circuits.*

Fig. 9 shows the circuits of the Mark III* Fullerphone. The lettering of the figure corresponds to that of Figs. 1 to 6.

This instrument provides for telegraphy and telephony either independently or simultaneously on the one line without further apparatus. When the receiving buzzer is not working the buzzing call from distant station is heard both in the head receivers and in the hand set—or if the hand set is not plugged in—then only in the head receivers.

When Fullerphoning the Morse signals are heard in the head receivers only.

When speaking and telegraphing the speech is heard in the hand set and the Morse signals in the head receivers.

In order to show clearly the operation of the various circuits Fig. 9 is dissected into Fig. 9—A, B, C, &c.

It should be noted that when the 4-pin Plug, No 406 (Fig. 1—N) is inserted the line is completed through the receiver of the hand set. When N is withdrawn the receiver sockets are short circuited by a spring contact.

CHAPTER III.

Instructions for Working.

11. *Connecting up.*

1. Connect lines or line and earth to terminals marked L1 and L2 on instrument.

2. See that the cells in the battery compartment are making good connection with their spring contact strips.

3. Turn Morse key, Figs. 1, 3, 4, 5—D into working position.

4. When line is idle, switch A (on instrument) should be in normal position (handle horizontal). A buzzing call, from distant station, will then be heard in the head receivers, Fig. 1—G, and in the hand-telephone also, if this is plugged in. The batteries are not working and buzzer is not running.

5. *To Call.*—Move switch A, Figs. 1, 3, 4, 5—K downwards into call position. Do this two or three times until an answering buzz is heard in the head receivers (and hand set if connected).

The outgoing call is also heard.

6. *To answer a Call.*—Move switch A to " Call " for a moment and then to " send and receive."

7. *Sending and Receiving.*—Switch A to " send and receive," operate Morse key. Buzzer must be running or no signals will be heard. Outgoing and incoming signals are both heard in the head receivers.

On completion of messages return switch A to normal horizontal position.

The receiver, during a message, can always stop the sender by working his Morse key.

8. *Speaking.*—Connect hand telephone set by inserting the plug, Fig. 1—N, into sockets, Figs, 3, 4, 5—T. Switch A may be either at normal or " send and receive." Keep the switch in the handle of hand set pressed while speaking or you will not be heard.

9. *Note.*—Speaking is only to be resorted to when specially permitted, it is not immune from overhearing in the same way as the Fullerphone signals.