APPENDIX C.

REPORT FROM CAPTAIN H. B. JACKSON, OF "DEFIANCE," ON EXPERIMENTAL TELEGRAPH WITHOUT CONNECTING WIRES.

Admiralty decision after the Experiments.

The experiments mentioned in last year's Annual Report, carried out independently by "Defiance" and Signor Marconi, with apparatus for electric signalling without wires, have been continued and given results sufficiently satisfactory for the Admiralty to decide on two complete sets of more powerful apparatus being manufactured and prepared in "Defiance" for a practical trial in sea-going ships.

Distance to which Signals have been sent.

The telegraph constructed in "Defiance" has sent reliable signals to a distance of 5,800 yards, through intervening hills and ships, with a transmitter worked with an induction coil, capable of giving a 6-inch spark in dry air.

Mr. Marconi's apparatus has done the same with an 8-inch spark coil; and using an 18-inch spark, he has easily sent signals 9 miles across the Bristol Channel, and at Spezzia succeeded, with a 10-inch spark coil, in signalling between two ships at a distance of 12 miles.

Speed of Signalling.

A speed of about 10 words per minute is obtainable, and the signals are recorded on a Morse inker or sounder as desired.

Vessels in which it has been tried.

In the experiments carried out at Devonport, the transmitter was mounted in the "Defiance," or "Scourge" gunboat, and the receiver in either of these vessels, and occasionally on board other ships in the harbour, and in torpedo boats, and the ship's steam pinnaces.

The following is a description of the apparatus (see Plates 27, 28, and 29).

Transmitter.

The Transmitter.

Induction Coil.

The transmitting apparatus consists of a Hertz oscillator actuated by an induction coil, which is worked from the electric light mains through a suitable resistance, or direct from six secondary cells, a special signalling key being inserted in the primary circuit. The coil is enclosed in a rain-tight casing, and the conducting wires to the primary, and from the secondary, are led through ebonite glands.

Oscillator.

The oscillator or transmitter consists of four 3-inch brass balls; the opposite diameters are platinised to prevent wear and oxidation through the continual sparking which takes place between them when in use. The balls are separated by glass discs, and enclosed in hermetically sealed wooden casing, from which they are insulated by ebonite strips and a glass shade. The two centre balls are $\frac{3}{8}$ of an inch apart, and the two outer ones $\frac{1}{4}$ of an inch from the two centre ones. These distances are such as to be well within the sparking limits of the induction coil, the

Connections to Coil.

ends of whose secondary coil are attached to the two outer balls. The oscillator stands vertically above the induction coil, and the bottom ball in it is connected to earth though the hull of the ship, and to the top ball an insulated wire is attached which is triced up to the masthead of the vessel. Perfect insulation of the three upper balls and the masthead wire is of the greatest importance, but very thick insulation seems unnecessary, pattern 600 cable having been used with very

Masthead Wires.

satisfactory results. Two masthead wires are preferable, provided they are of the same length, one wire being led up from each netting, and taken round ordinary telegraph insulators at the bends, to the transmitter, placed in any part of the ship, but preferably amidships on the upper deck, or under the bridge.

Differences in new Instruments.

In the new transmitters, now under construction, 10-inch spark coils will be used, which will be embedded in paraffin wax, the balls will be 4 inches in diameter, of a light aluminium alloy, to save weight, the casing will be of ebonite; and the mast head wires of a special cable used for open air work with high tension currents, with very high insulation resistance.

The Receiver.

Masthead Wires also to Receiver.

To pick up the signals transmitted through the air from the masthead wire in the sending ship, a similarly fixed wire is required on board the receiving ship. The E.M.F. induced in this wire affects the receiving tube to which it is attached, reducing its resistance sufficiently to allow a single Leclanché cell which is joined in the circuit with the tube and a relay to actuate the latter.

Details of its Action.

The other pole of the tube is put to earth through the hull of the ship. When the tongue of the relay moves over, a local battery, working through a vibrator and Morse inker (or sounder), causes the vibrator to tap the tube and so restore it to its original high resistance, and records a signal on the sounder or inker, the tube is then instantly ready to be affected by another signal, and so rapid is its action and that of the relay, that a long in Morse code is recorded as such on the sounder, when the various parts of the apparatus are properly adjusted, the sounder working slower than the relay.

Differences between "Defiance" and Marconi Plan.

Plate 27 shows a diagrammatical sketch of the receiver circuit as fitted in the "Defiance," and also the actual arrangements of the various parts in their practical form. Plate 28 shows the arrangement of the circuit adopted by Mr. Marconi, from which it will be seen that considerable differences in detail exist between them, and in arrangement of local circuit.

As stated in last year's Report, the receiving tube consists of a glass or ivory tube one-eighth of an inch in diameter, with two well fitting plugs one-fortieth of an inch apart, with suitable external connections, the space between them being half filled with moderately fine metallic filings of hard non-oxidisable metal or alloy, of moderate specific gravity and electrical conductivity. The number of tubes in parallel circuit is not necessarily limited to a single one, a double one will probably be used in the instrument now under construction. Details of Receiving Tube.

A double switch is added by which both the tube and the local circuits can be switched off when required, and by placing the switch in an intermediate position, an inductive resistance of 250 ohms can be inserted in the masthead wire, which it is advisable to do when the transmitting wire is within $\frac{1}{4}$ mile of the receiving wire, or otherwise the strong induction of the former on the latter may tend to demagnetise or affect the relay, and render a readjustment of it necessary. Switch.

Inductive resistances of 35 ohms, 40 S.W.G. copper wires, are also inserted in the tube circuit between its poles and that of the battery relay, to offer sufficient self-induction to the electric waves, and so prevent them passing through the relay instead of actuating the tube, at long distances. These resistances, and in fact all the best resistances for each part of the instrument, have only been found by exhaustive experiments, and are of great importance in affecting the speed, reliability, and distances to which signals can be received. These resistances are given in the plan. Choking Coils.

The vibrating hammer, or tapper, is simply an ordinary trembling bell, but it has been specially constructed, for rapid action, to tap the tube underneath, and to be easily adjusted as regards the distance through which the hammer works, and the strength of the blow it strikes. Its careful adjustment is of great importance, but when once adjusted requires little or no attention, a point which is claimed also for all the other parts of the receiver. Tapper.

The relay, tapper, and recording instrument are each shunted by a non-inductive resistance, to reduce sparking and self-induction. It is most necessary that the latter be almost entirely eliminated, or otherwise the induction of the local circuit will re-actuate the tube, and cause a continuous "long" to be recorded. Shunts.

A convenient means of testing the receiver, without the transmitter, is by means of an ordinary trembling bell, as when worked by a single cell and small key in the circuit, its induction will actuate the instrument at a distance of several feet from the masthead wire, and will show clearly whether it is in good adjustment. No differences in the future instruments will be introduced, the arrangement of the receiver having proved satisfactory. The receiver can be placed in any part of the ship. Tester.

Advantages of this System of Signalling for Naval Purposes.

In the event of the apparatus proving satisfactory in a practical trial in sea-going ships, the following advantages over other systems of signalling may be expected from it. Advantages of the System.

It will be equally efficient in a fog or thick weather, during day or night, as in fine weather, and much more rapid than any system of signalling yet adopted. Equally reliable Day or Night, Clear or Thick Weather.

Providing it is reliable up to 5 or 6 miles, it will be invaluable for scouts in thick or hazy weather; and at night, as well as by day, signals can be sent in the presence of strangers without their knowing that this is being done.

Signals can be exchanged between vessels within signalling distance, but out of sight of each other owing to intervening land.

In harbour, at an important base of operations in war time, telegraphic communications between ships in harbour and the shore can be established without laying a cable, a spare instrument being landed for the purpose; within a limited distance, outlying guard boats could communicate intelligence of attacks, &c. to the ships in the harbour they were protecting.

All signals sent and received can be automatically recorded on the tape without any attention on the part of the signalmen. All Signals can be automatically recorded independently of Signalmen.

On the other hand, it possesses the following disadvantages, which would be a bar to its ever entirely superseding any of the existing methods of signals, except fog signals. Disadvantages.

Only one ship can make a signal at any time. If two or more ships try to signal at the same time, their messages would be both recorded, and would probably render both unintelligible. This would necessitate similar rules as are at present in use for fog signalling.

Further experience with this apparatus has modified the views expressed in last year's Report relative to the theory of its action, especially since the introduction of the masthead wires, which were first proposed by Mr. Marconi, though the experiments in the "Defiance" were gradually leading up to this method, as being the most practicable for increasing the distance at which signals could be recorded. The following is considered to be the manner in which the signals are transmitted:— Theory.

On pressing the key at the sending station, the induction coil, on the break of the primary circuit, by its contact breaker, changes the two outside balls of the oscillator to a great difference of potential; this induces changes in the inner balls till the E.M.F. is sufficient to cause a spark to pass between them. This spark is oscillatory (the oscillations probably numbering several millions per second), and vary inversely as $\pi \sqrt{L.S.}$, when L. is the self-induction, and S. the capacity of the balls.

These oscillations induce corresponding ones in the two outer balls; that is, charge them alternatively to very high differences of potential. This would tend to cause a current back through the secondary of the induction coil, but owing to its great self-induction, this is practically impossible, and the electrical charges instead flow up and down the masthead wire, which has but little self-induction, and are dissipated in heat and electromagnetic induction, whose intensity diminishes nearly directly as the distance.

Though the actual current in this wire is very small, the rate of change is enormous, and as the induction in a neigbouring circuit (*i.e.*, the masthead wire at the receiver) varies directly as the rate of change, the more rapid the oscillation the greater the effect produced; also for parallel wires, short in comparison with the distance between them, the induction in the receiving wire or the impressed E.M.F., E, varies as the product of their length by the distance between them. This impressed E.M.F. will also vary with the E.M.F., E^1, at the transmitter; so if h h^1 be the lengths of the masthead wires, d the distance between them, and n the number of oscillations per second, we have:—

$$\text{E varies } \frac{n\,h\,h^1\,E^1}{d}, \quad \text{but } n = \frac{1}{\pi\sqrt{L.S.}}$$

$$\therefore \text{ E varies } \frac{h\,h^1\,E^1}{d\,\pi\sqrt{L.S.}}$$

$$\text{or } d \text{ varies } h\,h^1\,\frac{E^1}{E}\;\frac{1}{\pi\sqrt{L.S.}} \text{ or } d = \frac{K\,h\,h^1\,E^1}{\pi\sqrt{L.S.}\;E.}$$

where K is constant; from which it will be seen that to increase the distance at which signals can be received, the masthead wires should be as long as possible, (within certain limits), and the E.M.F. or sparkling distance of the coil should be as great as possible, and that the self-induction and the capacity of the balls should be small and the E.M.F. which wiil actuate the receiving tube should also be as small as possible. These points have been carefully considered in the apparatus designed to agree with these laws so far as possible with due regard to its practical form.

Practical Experiments agree with Theory.

The experiments carried out with the different lengths of wire and different induction coils have agreed approximately with this formula.

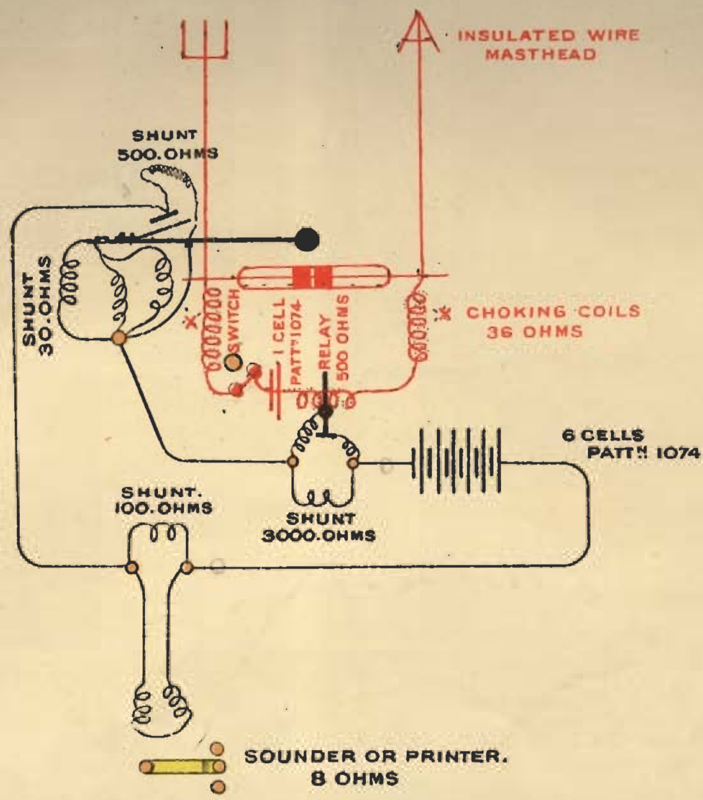
Effect of Earth and Capacity.

The function of the earth connections at both instruments which increases the distance to which signals can be transmitted, is probably due to the capacity of the earth increasing the actual electric charge flowing along the earth wire with a corresponding equal and opposite flow up the masthead wire. That additional capacity at the end of the wire is of importance, and is a point on which Mr. Marconi lays great stress, and in many of his experiments he has used a large zinc drum or a balloon covered with tin foil to which his masthead wire was attached as shown in Plate 28. This fitting is, however, impracticable on board ship.

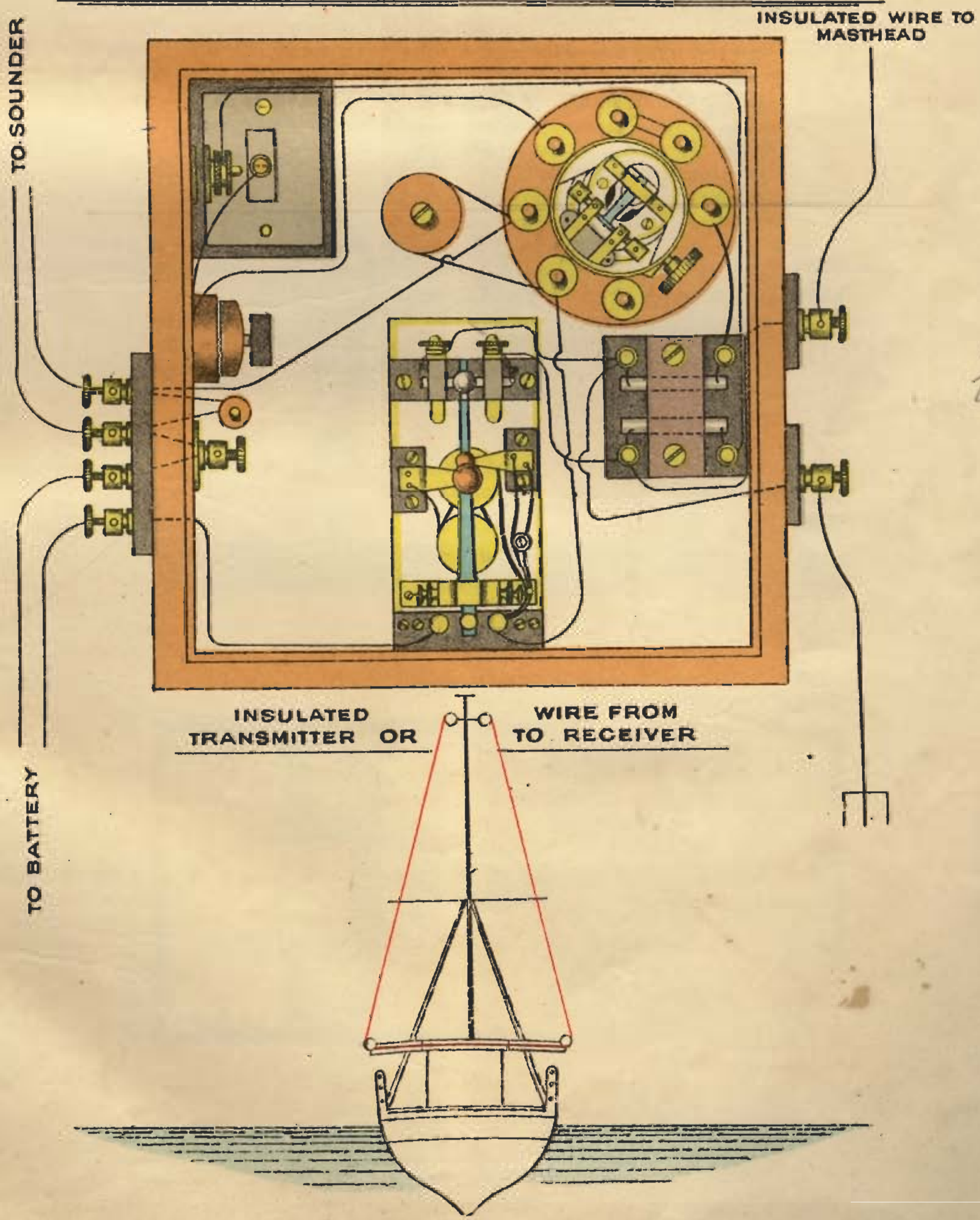
Danger of Explosions.

Experiments have shown the impossibility of firing Service fuzes or detonators by the induction of the transmitter, that the compasses are unaffected, and that shocks are practically unobtainable, unless the insulation of the masthead wires is so faulty as to be useless for signalling.

SKETCH OF CIRCUIT OF RECEIVER.

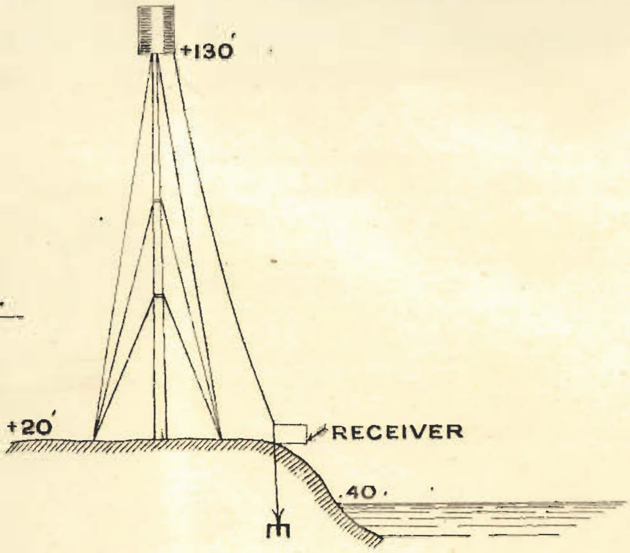


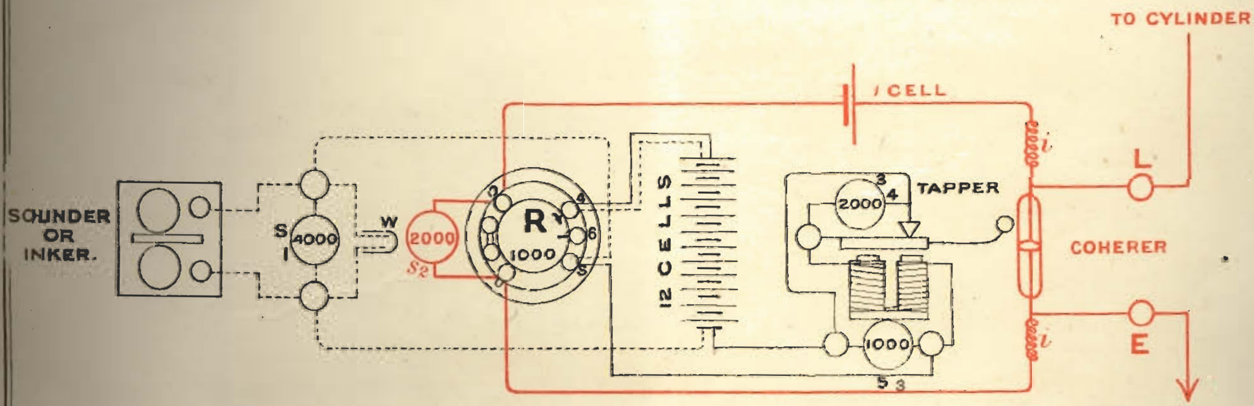
BOX CONTAINING RECEIVING APPARATUS.



Mr. Marconi's.

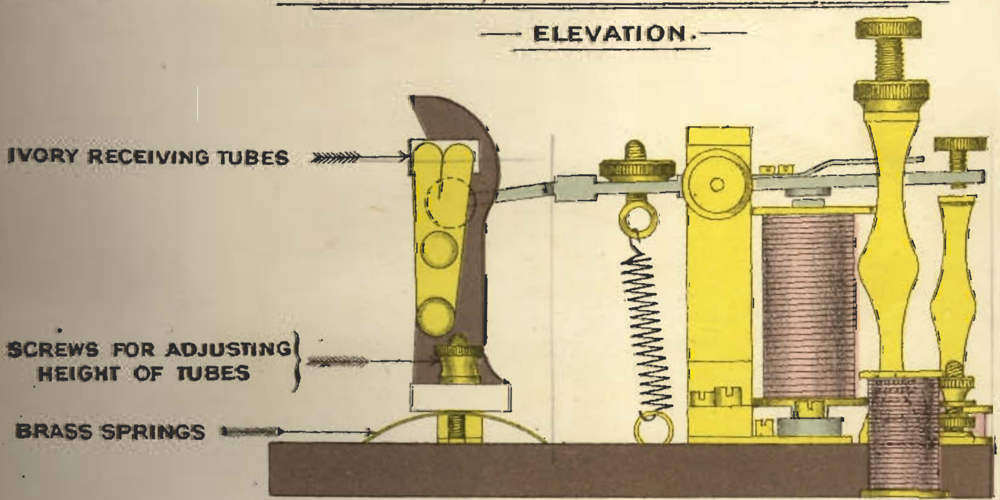
Arrangement of Circuit.





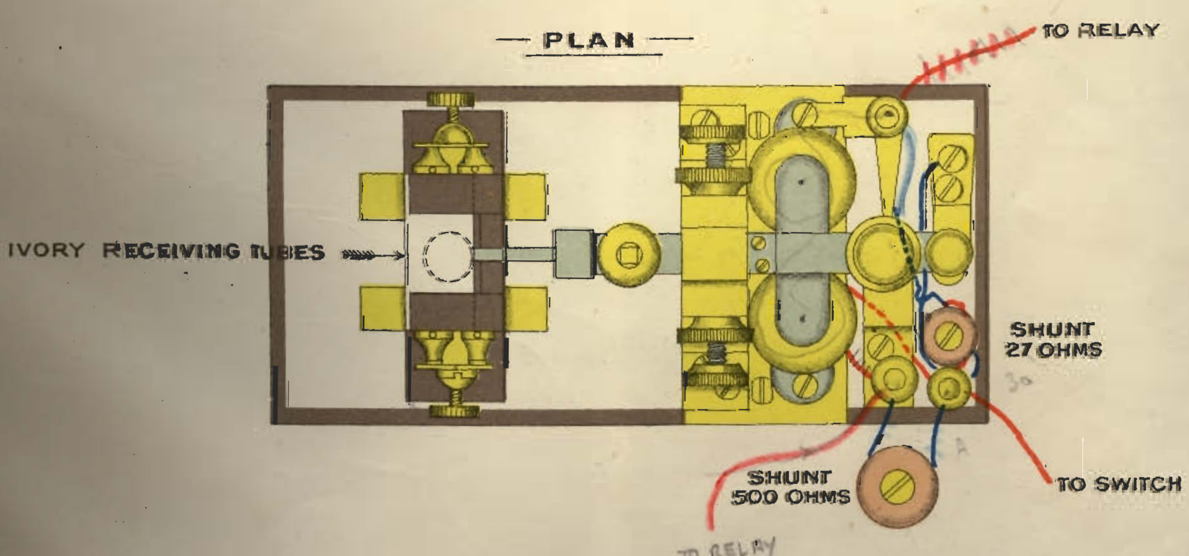
TAPPER, LATEST PATTERN.

ELEVATION.



1/2 Scale

PLAN



Plan of Apparatus used for Telegraphing, Without Wires Between "Scourge" and "Defiance".