APPENDIX D.

WIRELESS TELEGRAPHY.

THE FOLLOWING EXTRACTS ARE TAKEN FROM THE REPORT ON EXPERIMENTS WITH WIRELESS TELEGRAPHY CARRIED OUT AT DOVER BY MR. W. H. PREECE.

These experiments were mainly designed with a view of determining the laws which govern this method of transmission ; and they consisted of two separate series of trials.

In the first vertical wires were erected at distances varying from half a mile to three miles from one another, and the varied experiments referred to below were made in order to ascertain the best conditions under which the system could be worked.

The vertical wire arrangement has the advantage of simplicity, but it carries with it the disadvantage that the radiation takes place in all directions, so that any number of receiving sets may be placed at any points within the visible horizon and the transmitted messages may be read at all these points if within the distance limit of the apparatus. In fact, the effect is equivalent to signalling with an open flash light, which may be seen all round the horizon.

The substitution of radiators and receivers fixed in reflectors, where this is possible, would obviously minimise this evil, and the effect would be equivalent to signalling with the heliograph, which concentrates a beam of light in a definite direction alone. The second series of trials was made with apparatus to meet this end.

The transmitting station was fixed at Fort Burgoyne, but the receiving apparatus was movable, communication being also kept up between them by flag and heliograph.

(1.) *Vertical Wire Experiments.*

Vertical wires.

These commenced with a large number of preliminary tests between two stations situated a mile apart, with the object of ascertaining the best conditions under which to complete the series of experiments.

Poles were erected fitted with blocks and pulleys for drawing up the conductors to any desired height up to the limit.

Both poles were without stays of any kind so as to avoid inductive interference.

Nature of conductors.

As the result of a large number of experiments it was found that the gauge of the transmitting wire could with advantage be increased, whilst the reverse held with the receiving wire. In this latter case the best results were obtained with 12 mils. silk-covered copper wire, but the advantage over 40 lbs. G. P. was slight.

The apparent reason why a small conductor presents an advantage at the receiving end seems to be that the lower portion of the wire is ineffective, or less effective in producing useful E.M.F. than the upper. Probably some of the waves are absorbed by the surface of the earth and others are reflected into space by the undulations of the ground. By reducing the gauge of the receiving wire the capacity is reduced, and with such a small induced charge as that which is observed at a considerable distance the reduction of the capacity is of more importance than the increased resistance.

Bare conductors did not seem in any case to be so effective as covered conductors, and broad copper tape conductors appeared to be no more effective than cylindrical wires.

Multiple wires, arranged as a screen, were no more effective than single wires.

Somewhat similar results were obtained by Marconi in his experiments at Salisbury.

Iron wires showed no advantage, or otherwise, over copper.

As a result of these trials in the later experiments a cable of seven 16 wires, rubber insulated, was used at the transmitting end, and a single wire (40 lbs. G.P. covered) at the receiving end, as the arrangement was found to be as effective as any.

Effect of power employed.

In all cases where vertical wire trials were concerned the large 18-inch spark coil was found to give the best actual results, but no advantage could be obtained by working this coil with a stronger current than was necessary to maintain a fairly regular 7-inch discharge (*i.e.*, 5 ampères).

This, no doubt, arises from the fact that the rate of make and break with the voltage necessary to obtain the maximum discharge becomes very slow, with the result that the transmitted signals are broken.

Below the 5 ampères the distance at which signals can be obtained rapidly diminishes. A small induction coil giving a regular 4-inch or 4½-inch discharge, with a current of 8 or 10 ampères gives a relatively better effect in the proportion of 4 to 3 as regards length of spark, but much worse as regards current used.

There is no doubt that a great improvement is possible in the provision of a specially-designed induction coil, fitted with a reliable and regular make and break. The present form is irregular and troublesome, and not fitted for use by untechnical persons.

Parallelism of wires.

A distinct advantage was found to arise when the transmitting and receiving wires were parallel to one another, but at the same time the signals would not be altogether destroyed by leading the wires down from the pole so that they were kept at right angles to one another, provided that such an excess of height was used as to give an ample margin under normal conditions.

Effects of resonance or tuning.

In the case of simple vertical conductors the effect is not well marked. That is to say, the lengths of the receiving and transmitting wires may differ largely, without affecting the signals. If, however, the length of one wire approaches one half that of the other, then the effect becomes very apparent. If the transmitting wire, for instance, is twice the "height" of the receiving wire signals may be obtained if the lengths of the two conductors are not too widely different, but if the length of one be made half the other, the signals are stopped. This would seem to point to the fact that there is not a large number of oscillations accompanying each discharge of the transmitting wire under these circumstances.

When capacity, in the shape of large copper plates 4 feet square, is connected to the top of the vertical wire at either end, then the tuning or resonance effect becomes much more marked. If both ends be made symmetrical, a considerable reduction is obtained in the height necessary for good signals.

That this is the effect of resonance, rather than capacity alone, was found by altering the amount of capacity. When made larger or smaller at one end alone, the signals became worse than with simple conductors. The essential factors in tuning appear to be adjustment of capacity at the top of the wire, and total length of conductor.

The gauge of wire used does not appear to affect the question.

Thus a seven 16 wire with capacity on transmitting end is in tune with a 12 mil. copper wire of same length, and having a capacity on the top at receiving end. The larger the capacities employed, the more marked is the effect of resonance, and the less the length necessary to signal a given distance.

This would appear to point to the fact, that when a capacity is added to the transmitting wire, the number of oscillations taking place at each discharge is very much increased, thus giving the resonance time to make itself appreciated.

Coherers.

Marconi's coherers are undoubtedly the most sensitive that have been experimented with at present, as the more delicate ones are affected by the radiation from an ordinary trembler bell at distances much in excess of those at which other forms will work.

These very sensitive tubes, however, do not seem to be very stable.

They act very well for a short time, but rapidly lose sensitiveness. Marconi's experience confirms this, as he does not recommend very sensitive tubes for practical use. The tubes, moreover, appear also to be liable to crack. None of Marconi's coherers should have more than one milli-ampère of current pass through them, nor should they be exposed to an E.M.F. of more than 1·5 volts, or their sensitiveness will be destroyed rapidly.

Coherers of moderate sensitiveness appear, so far, to be stable if the foregoing conditions of working be not infringed.

Miscellaneous trials.

It was found, when using the vertical wire arrangement, that any surplus length of transmitting or receiving wire could be made up into a spiral without affecting the signals.

Such a helix at the receiving end does not produce E.M. induction, or at any rate, not sufficient to actuate the coherer.

Good earths would not appear to be necessary at either end, as a capacity, if sufficiently large, will act equally as well in either case; placing the spark gaps half way up the transmitting wire does not give such good results as the ordinary plan.

Law of the circuit, a simple and practical formulæ, which is applicable to assisting work with vertical wires is

$$D = K. I. I'.$$

where D = a distance in yards over which signals can be transmitted.
K = a constant depending on the energy of coil and rapidity of its rheotome.

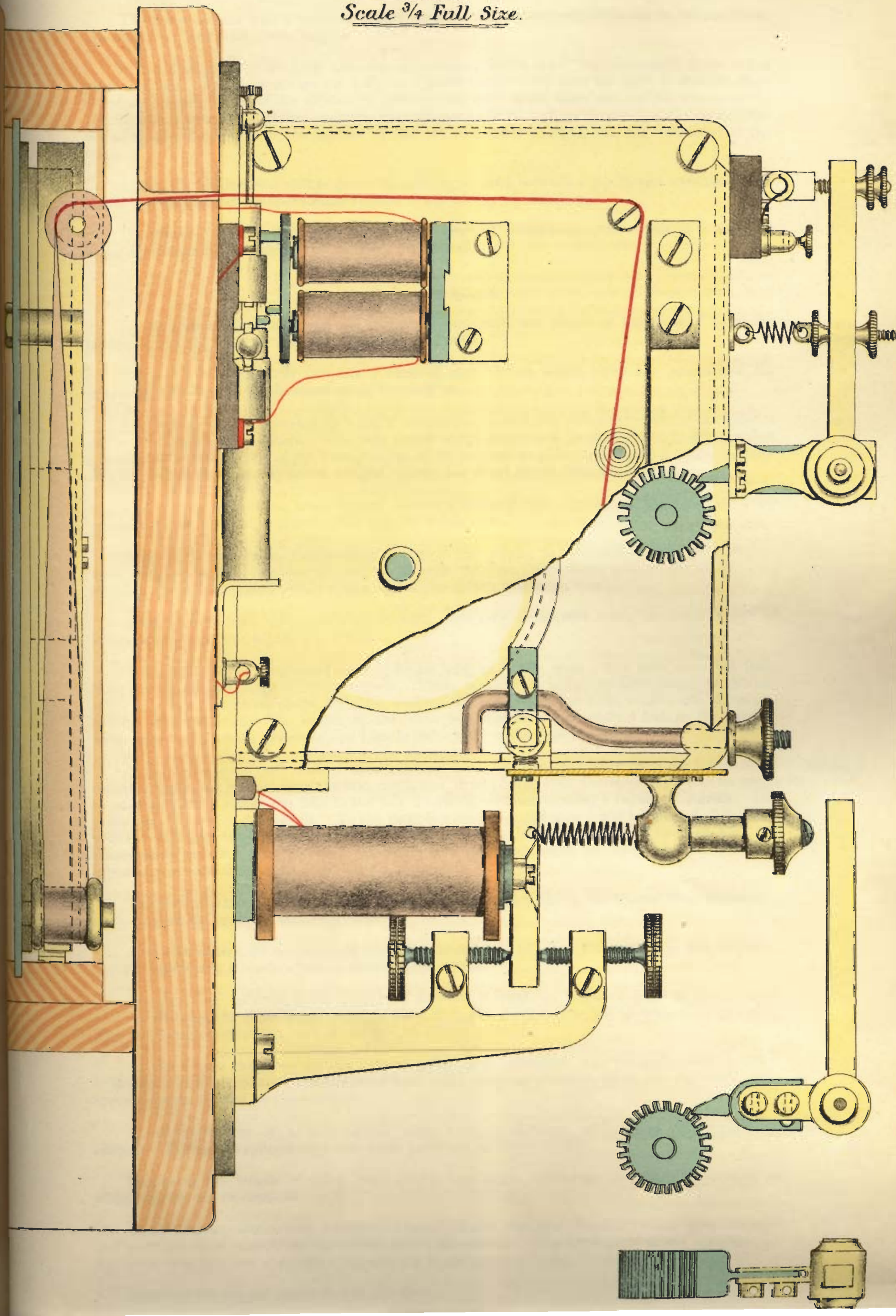
I. and $I.^1$ the effective heights of vertical conductors.

Considerable differences were sometimes obtained in the products of the two heights where one was higher than the other, but for single vertical wires, preferably with the vertical conductors at each extremity of the same height, it may be said an average height of 50 at each end, giving a

Telegraph Printer

Fitted for Wireless Telegraphy with Automatic Starting Arrangement, and Mechanical De-Coherer.

Scale ¾ Full Size.



product of 2,500 feet is necessary to attain a distance of one mile. The effect of adding capacities at the summit of the vertical conductor was to increase the range almost 20 p.c.

There are reasons which render it highly probable that a greater distance can be attained over sea than over land with given heights of wires.

In the first place all the long distance experiments which have been successful have taken place over sea. Again, as the sea has a higher specific conductivity than the land, it should reflect more, and absorb fewer, of the electric or electro-magnetic waves than the surface of the earth. During the course of the electro-magnetic experiments between Lavernock and Flat Holme in 1892 the effect of reflections from the surface of the sea was most marked, and the fact noted at the time.

Again, the hollows and valleys generally existing on land between the points of communication would probably absorb an appreciable amount of the energy of radiation.

The Marconi's coherers may be of various degrees of sensitiveness, the result it is believed being dependent on the quantity of mercury introduced.

(2.) *Reflectors.*

In this system the transmitting and receiving instruments are placed in the focus of parabolic reflectors, and the lofty vertical wires are dispensed with. **Experiments with reflectors.**

The transmitting reflector projects a beam of rays, part of which enter the aperture of the receiving reflector and are focussed on to the receiver.

The radiations are generated by a Righi transmitter or radiator with the centres of the spheres in the focal line of the parabola. The focal length of the parabola is such that this length is either a quarter or three-quarters of the wave lengths of the oscillations generated by the spheres, in order that the reflected waves may assist, and not oppose, the direct waves from the spheres.

The spheres in question were 10-inch diameter, made of thin copper, the focal length of the parabola 1 foot, and the aperture 6 feet high by 4 feet wide.

Trials with these were first made at a range of 800 yards; at this distance very good signals were obtained with $\frac{1}{8}$ ampère of current through the Post Office large coil, or about the same strength through the small coil, giving a $4\frac{1}{2}$-inch or 5-inch maximum spark.

Good signals with this very weak current were only obtainable when the total length of wings and coherer was adjusted to 2 feet.

The actual copper wings used were $6\frac{1}{2}$-inches long by $\frac{1}{2}$-inch wide. Any wide deviation from these dimensions interfered with the signals. Thus, making the wings an inch longer or shorter, or using wings instead of plates, or, again, making the wings 4 inches wide, caused the signals to become discontinuous. The length of the wave was therefore apparently 4 feet, as the neutral wave length of a lateral system of this kind is twice the length of that system.

Experiments were next made to ascertain how much the projected beam from the transmitting reflector expanded in traversing the 800 yards, and it was found that the receiving reflector could be moved laterally across the field to the left 75 yards, without causing a failure of signals. 100 yards gave discontinuous signals. To the right the receiving reflector could be moved 250 yards without affecting the signals; the difference was, no doubt, accounted for by the fact that the transmitting reflector was placed at an angle in a gun embrasure, the sides of which assisted materially in reflecting to the right but not to the left. **Expansion of beam.**

The vertical expansion of the beam was next measured by tilting the transmitting reflector so as to project the beam normally upwards.

It was found that the tilting could amount to as much as 15° from the vertical in this direction, and 20° backwards without affecting the received signals.

The receiving reflector could be turned laterally through an angle of quite 30° right or left without affecting the signals, and could be tilted from the vertical quite 20° backwards or forwards. The preceding observations were all made with hollow spheres.

At the 1-mile range no signals beyond a few stray occasional taps could be obtained either with empty or filled spheres, and the stray taps could only be obtained when the reflectors were approximately sighted on one another.

At three-quarters of a mile signals could only be obtained with 10 or 12 ampères of current. Filling the spheres with salt water produced no better results.

Increasing the length of spark gave only a very slight advantage in matter of distance at which signals can be obtained.

The Righi transmitter, with 4-inch solid brass spheres, was next placed in transmitting reflector and gave the same results as the former larger transmitter. The adjustment of the apparatus in the exact focal line was apparently unnecessary to the radiator in the transmitting reflector.

Earthing the copper reflectors had no effect.

When the receiving reflector was placed on the ground a somewhat worse result was obtained than when raised to a height of 3 feet. It would therefore appear that the reflectors should be raised a considerable height above the ground to get the best results.

On the whole no arrangement or combination tried would give signals at any distance over three-quarters of a mile.

A copper plate, 4 feet square, held immediately in front of the receiving reflector screened the atter if held 3 or 4 feet from the aperture, but produced no effect at 6 feet.

EXTRACTS FROM A REPORT, BY COMMANDER HORNBY, ON SOME EXPERIMENTS WITH WIRELESS TELEGRAPHY, CARRIED OUT AT THE NEEDLES, BY M. MARCONI, ON THE 7TH MAY 1898.

The experiments carried out on this occasion were merely calculated to show the feasibility of transmitting invisible signals from one station to another at a considerable distance, without the aid of a connecting wire, where by means of a suitable apparatus they could be received and recorded on an ordinary Morse telegraph recorder. In this M. Marconi was entirely successful, the signals sent from Bournemouth being received with remarkable clearness at Alum Bay, a distance of $14\frac{1}{2}$ miles, and *v.v.*; the speed of signalling being about 10 words a minute.

System of working "Transmitter."

The method of working may be briefly explained as follows: The sending apparatus consists of an ordinary Ruhmkorff induction coil, capable of giving a 10-inch spark, joined up to a battery with a key in the circuit, by means of which the circuit can be made and broken in practically the same manner as with an ordinary telegraph key. The two ends of the secondary wire of the coil are joined to two $\frac{3}{4}$-inch brass balls about 1 inch apart, to one of which is also attached a long insulated wire, or wires, triced up to a flagstaff.

On the present occasion the wire consisted of three parts arranged in a ladder form with wooden rungs. The other ball is joined to earth. Whenever the key is pressed the coil is brought into action, and sparks pass continually between the balls. These sparks are the expression of oscillatory currents produced by the coil, the rate of oscillation being estimated under ordinary circumstances at about 30 million per second. These currents also surge up and down the vertical wire, and each one propels a wave or undulation radially outward through the ether, somewhat in the same way that ripples spring outward when a stone is dropped into still water.

These undulations travel away through space in much the same way as light or sound waves, being, moreover, reflected by metal surfaces on which they impinge. Also if they encounter any vertical conductor of electricity, they generate in it a series of definite electrical pressures tending to force currents of electricity along the conductor, and if this is in connexion with a suitable receiving arrangement the receiver will be actuated by these currents and the signals recorded.

Receiver.

The receiving apparatus consists of a glass or ivory tube known as a "coherer," in which are two silver plugs or balls, about $\frac{1}{40}$ inch apart, the space between them being filled with nickel and silver filings. Wires are led in at either end of the tube, and to one is attached the vertical receiving wire, and to the other a wire connected to earth.

The two wires from the coherer are also joined through two choking coils of wire to a single cell and a telegraph relay.

Under ordinary conditions the electrical resistance of the coherer is so great that the single cell cannot force sufficient current through the relay to work it; but directly one of the currents induced in the receiving wire reaches the coherer it causes its electrical resistance to drop very greatly, sufficiently so to allow the single cell to work the relay. If the coherer is tapped or shaken mechanically it reverts to its original condition, and is ready for the next wave.

Distance of signalling.

The distance to which signals can be transmitted and received depends mainly on the vertical height of the wires, 30 feet being allowed for 1 mile and the distance varying as the square of the height (*i.e.*, 60 feet gives 4 miles, and 120 feet 16 miles). This may be accounted for by considering that the undulations are imparted to the surrounding medium from each minute length of the vertical wire, thus the greater its length the greater will be the disturbance propelled through the atmosphere. Similarly, the greater the vertical length of the receiving wire the larger will be the interception by it of the undulations, and the greater, therefore, the electrical effect produced in it by them.

At each station a set of sending and receiving apparatus are necessary, the receiving apparatus (except the recorder) being enclosed in an iron box, to screen it from the effects of the sending coil, &c., which would otherwise damage it.

The same vertical wire can be used to send or receive, being shifted over from transmitter to receiver as required.

Difficulties of working.

At present the chief difficulties in the employment of this method of signalling seem to be :—

(1.) Only one instrument can be sending at a time, and this will actuate all receivers within its range. A second instrument trying to send at the same time would also affect all receivers and produce an unintelligible jumble of the signs. Signor

Marconi professes to have discovered a method by which he can attune two transmitters and receivers, and that instruments so arranged will only receive signals from the transmitter which is in tune with them, and will be totally unaffected by other instruments sending in its vicinity. This he effects by means of a coil of wire containing an exactly equal number of turns inserted in both sending and receiving wires. This arrangement was unfortunately not shown on the occasion of the visit to Alum Bay.

(2.) Difficulty of obtaining sufficient height for the masthead wire. Signor Marconi proposes to carry out experiments with balloons or kites to overcome this difficulty, and of course in ships a considerable vertical height is generally obtainable.

In the "Defiance" it has been found advisable for ship work to run a wire down from the masthead to each netting, thus obviating the screening effect of funnels, &c.

(3.) Preserving the insulation of the sending coil in wet weather, sparks being apt to fly about, and nasty shocks received by the operators.

This is not unsurmountable, but would necessitate the apparatus being adequately housed in a cabin or other well protected place, and Signor Marconi has found that signals are actually better transmitted on a foggy day than on a fine one.

(4.) Sufficiently delicate adjustment of the receiving apparatus, especially the relay, and also the de-cohering of the tube by the tapper.

Signor Marconi stated that the apparatus had been working untouched for five weeks, and that *once* adjusted the apparatus should remain correct for a considerable time.

Undoubtedly this method of signalling has great possibilities, and its development by Marconi should be carefully watched, especially if his claim is substantiated of being able to confine his signals to certain instruments, the signals being totally unaffected by other instruments not absolutely in accord with them.

The advantages which this method of signalling would possess for naval purposes are clearly summarised in Captain H. B. Jackson's report given at page 109 of A.R. 1897. From recent reports from "Defiance," it appears probable that a mechanical tapper will be introduced, thus simplifying the electrical connexions and adjustments, and increasing the speed and certainty of signalling.

An account of progress up to date will be found on page 7 of A.R. 1896, and page 108 of A.R. 1897.

The coherer is partially filled with metallic dust (96 per cent. nickel and 4 per cent. silver), and the air exhausted, the vacuum, however, being not important. **Remarks.**

The form of the filings, however, is important, those of a jagged or sharp form being the most sensitive. They are selected under the microscope, and should be as nearly as possible of a size. The amount per tube is only about 20 to 25 grains.

REPORT FROM H.M.S. "DEFIANCE" ON TELEGRAPHY WITHOUT CONNECTING WIRES.

The experiments with the telegraph without connecting wires, which were commenced by Captain Jackson, and reported on in last year's report, have been continued, but so far without such results as will justify the turning over of the apparatus to seagoing ships. **Experiments.**

The difficulties are rather difficulties of manufacturing detail than difficulties of principle, and are mainly connected with the induction coil, an instrument which has hitherto never been used under other than lecture-room conditions, and which largely depends for its efficient working on the dryness of its surroundings. **Induction coil required to work under all conditions of the atmosphere.**

That it is possible to so construct and enclose a coil that it will work efficiently under all conditions of atmospheric dampness there can be no doubt, but it being a new point to require from the manufacturers, it necessarily takes some time to get them to move in the matter, unless at very great expense.

In this connexion, it should be noted that the condition of extreme dampness of the atmosphere is just that condition when this apparatus would probably prove most useful, viz., in fogs.

Further experience and working with the apparatus has made it apparent that some modifications can be introduced which will tend considerably to simplify the mechanism, and do away with minute adjustments which require skill, practice, and knowledge, so as to make it more practical for sea work. **Changes in apparatus.**

The electrical tapper introduced a complication of circuits and shunts which was very likely to cause trouble, and experiments have therefore been made with the view of using the clockwork of the printer to actuate a mechanical tapper; this arrangement (a sketch of which is shown on Plate 32) is found to work satisfactorily; the tapping is, of course, continuous, but this is found **Mechanical tapper introduced.**

not to have any injurious effect on the coherer; on the other hand, the action being purely mechanical, there are no inductive effects to get rid of, and it is an easy matter to adjust both the quality and force of the blow given.

Space saved.

Space also is saved by the introduction of the mechanical tapper; a very important consideration, and it is hoped that the box shown in last year's report will be made to contain the printer as well as the other receiving apparatus.

Metal receiving box required.

It is found that the receiving box must be made of metal, so that the effect of the sending instrument on the receiver at the same end may be reduced as far as possible.

High resistance relay proposed.

Having got rid of the electrical tapper, it is now proposed to try if a more sensitive relay of higher resistance can be used with advantage.

Transmitter.

With regard to the transmitter, it is found that the four large balls of the oscillator do not produce the improved effect expected of them, and so the apparatus is now being tried with only two balls of $1\frac{1}{4}$ inch diameter with a gap of from 1 to $1\frac{1}{2}$ inches between them, with apparently improved results.

Masthead wires.

It is found that wires to the masthead with a braided covering are bad in damp weather, as the damp coating causes the wire to act as a condenser, and so increases its capacity.

Synchronising.

The synchronising of the system is a point to which great attention is now being paid, and it is hoped and considered that it will tend to better results being obtained.