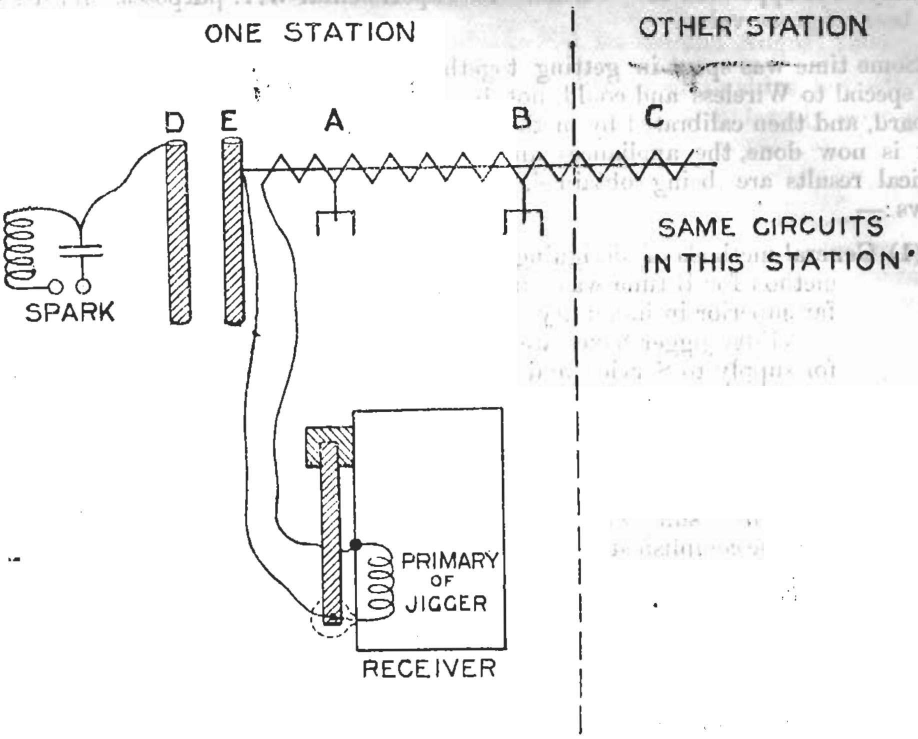
Instructional Circuits.

FIG. 18.



After much experimenting the circuit shown in Fig. 18 was adopted.

The sender consists of a self-inductance and capacity with a spark gap, fed by a coil in the usual way, and the electrostatic variations in one of the plates of the condenser influences D through a *short* piece of wire.

D and E are two bars of metal, about 3 feet long and ½ inch diameter, and are usually about 2 feet apart. D influences E electrostatically, and the strength of signals is adjusted by variation of the distance between them. E is connected to the core of a lead covered wire ABC, the lead covering of which is earthed in many places. The receiver is joined to the lead covering and to the core by means of wires going to the tomahawk switch and to the earth terminal of the box, inside which the usual jigger is connected in the ordinary way.

It is important that the lengths of these two wires should be approximately equal, and that the box itself be not earthed (except by the wire going on to the lead cover of the "energy pipe" ABC).

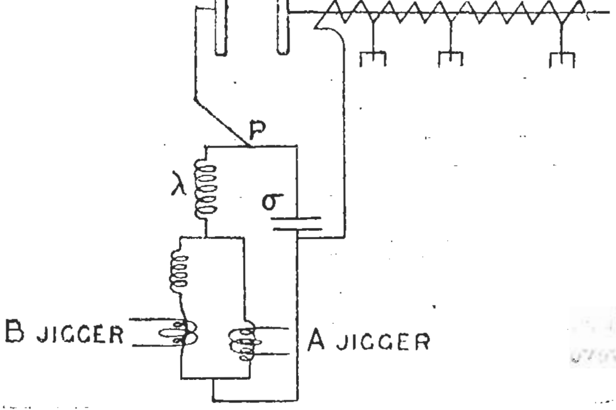
Another important matter is the earthing of the lead core of the energy pipe; it cannot be too often earthed, but it is particularly important that it be earthed at the point where it leaves one deck and goes into another.

Electric light wires are also a great bugbear; our circuits worked well until electric lights were introduced into these offices, and then the interference re-commenced, but was finally stopped by leading all electric light wires between the stations along the outside of the ship, and therefore screened from the long-distance offices.

In the "Hector," one office is down below in the lecture room on lower deck, the other office has been built right forward on the same deck as the usual offices for signalling to a distance are situated. The office on main deck is the difficult one to insulate.

Signalling can go on continuously on "A" tune on these instructional circuits, and on "B" tune to Portland, without mutual interference.

FIG. 19.



Experiments and instruction in actual signalling and receiving adjustments to various strengths of signals (adjusted by the distance between D and E) can go on simultaneously, but lately it has been thought that the instructional circuits should have both "A" and "B" tunes, and be able to practise double reception.

Further experiments have shown this is thoroughly feasible.

The receiving circuit was made up as in Fig. 19.

Where the energy pipe is connected to the two coatings of the capacity σ which, together with an inductance λ, forms an artificial 180 feet aerial, similar to the one used for designing jiggers. (*See* page 20.)

The A and B jiggers are joined up to the foot of the aerial λ in the usual way.

The sender at distant end was then adjusted to give off either the A or the B wave; and it was found the appropriate jigger alone responded.

Several of this latest pattern are now going to be fitted as soon as the instruments arrive—viz., 3 each in the "Warrior" and "Defiance," and 4 in the Signal School.

The offices will be arranged exactly similar to the standard office (*see* page 4), with all the artifices required stowed away behind a false bulkhead; so that everything will be worked, and look like, the real thing as found afloat.

We also hope to introduce in "Warrior" experimental circuits of this form for interference experiments; so that the subject of blocking out undesired interferences (*see* "Tuning," page 44) may continue, even though the proper aerials are in use.

Units and Formulæ now used.

In order to make calculations to adjust "tuned shunts," measure wave lengths, &c. in practical W.T.; a knowledge of the frequency or wave length is of little use until it is turned into "LS value."

By this term we mean the L and the S, which together have a frequency (and wave length) equal to that we are using.

Thus in the handbook of W.T., page 56, we have the formula:—

$$\text{Frequency} = \frac{48. \times 10^8.}{\sqrt{LS}} \qquad (1)$$

and this equation gives us (knowing the frequency) the "LS value" corresponding to it.

In this formula L and S are measured in absolute units (cm.), but in order to avoid the large powers of 10 occurring in this formula, we now measure L and S in thousands of centimetres.

That is:—

Unit L used in this report = 1,000 cm.

" S " " = 1,000 cm.

Therefore—

$$\text{Frequency} = \frac{4{,}800}{\sqrt{L_1 S_1}} \qquad (2)$$

And

$$\text{Wave length in feet} = 206 \sqrt{L_1 S_1} \qquad (3)$$

are the two formulæ to use for converting "LS value" into frequencies or wave lengths and *vice versâ*.

As it is puzzling to use the same quantity, the "centimetre," for two quite different purposes; and as 1,000 cm. of absolute inductance is also equal to the practical unit the "micro-henry" (the millionth of the henry), we call our unit of inductance the "micro-henry."

The 1,000 cm. of absolute capacity may be called the "kilo-centimetre" (as kilogramme), and as this unit is very approximately equal to one of the A and B tune Leyden jars, we usually call it the "jar."

Our units are therefore:—

Unit self-inductance = 1,000 cm. of inductance in abs. E.M. units.
= 1 micro-henry (mic.).

Unit capacity = 1,000 cms. of capacity in abs. E.S. units.
= 1 kilo-centimetre (k.cm. or jar).

Thus, referring to page 55, a two-fold 180-ft. aerial has an inductance of λ = 24 micro-henries, and a capacity = 0·56 kilo-centimetres; hence the "LS value" of the "plain aerial" wave is—

$$\lambda\sigma = 24 \times 0{\cdot}56 = 13{\cdot}5 \text{ micro-henry kilo-centimetres,}$$

and by formula (2) the wave length in feet is found to be 756 feet.

These units are used throughout this report. They are the result of much thought as to how to simplify calculations as much as possible, and will be found very convenient.

In making official reports wave lengths should be given in feet, in order to prevent misunderstandings.

Example I.

We wish to receive Poldhu on the roof aerial (No. VI.), shown on page 55. What inductance is required?

On page 36 we see that the wave length of Poldhu is 6,350 feet; and the LS value = 950 (this being obtained by equation (3).

On page 35 the **capacity of the roof aerial VI. is—**

$$\sigma = 1 \cdot 18;$$

therefore—

$$\text{Inductance required, L} = \frac{950}{1 \cdot 18} = 805 \text{ micro-henries.}$$

This L is the total required for resonance; to get the amount to be placed in the aerial, we must subtract from L whatever inductances we have *already* in the circuit; we have, let us suppose, a magnetic detector (80 mic.), and the inductance of the aerial (85 mic.) already in circuit. Hence the amount to add from the "tuner" is—

$$805 - (80 + 85) = 640 \text{ micro-henries.}$$

Example II.

We wish to receive B tune on a four-fold aerial using an M.D. What "tuner" do we require?

On page 36 we find B tune gives a wave of 1,150 feet, which has an LS value of 31.

On page 55 the four-fold Æ shown has $\begin{cases} \lambda = 20 \cdot 6. \\ \sigma = \ \cdot 82. \end{cases}$

Hence—

$$\text{Inductance required, L} = \frac{31}{\cdot 82} = 37 \cdot 8 \text{ micro-henries,}$$

but we already have the M.D. and aerial inductances, that is $(80 + 20 \cdot 6) = 100 \cdot 6$ mic. in the circuit, and yet to get into resonance we only require $37 \cdot 8$ mic.

It is evident, therefore, we cannot put in more inductance from a tuner. Our wave is already too long; and instead of artificially lengthening the aerial by L we must artificially *shorten* it, by the introduction of series capacity.

To Calculate the Capacity S required.

1*st Method.*

According to page 50 the LS valve of the aerial shown in Fig. 38 with a capacity S in series is—

$$(\lambda + l) \frac{S \ \sigma}{S \ +} = 31 \text{ (LS value of B tune wave)}$$

putting in the values of λ and σ for the aerial and of "l" (80 mic.) for the M.D. and equating this expression to the LS value of B tune we find that—

$$S = \cdot 494 \text{ kilo-centimetres.}$$

2*nd Method.*

The calculation can be simplified as follows:—

$$\text{We require for resonance } \frac{31}{\cdot 82} = 37 \cdot 8 \text{ mic.}$$

$$\text{We have already } (80 + 20 \cdot 6) = 100 \cdot 6 \text{ mic.}$$

$$\text{Hence the } \textit{surplus} \text{ inductance} = 62 \cdot 8 \text{ mic.}$$

This surplus we must neutralise by S.

Now in "tuned shunts," page 40, we state that an "acceptor" gives no D.P. between its terminals (that it has no surplus indutance or capacity creating a back E.M.F.) when its LS is equal to that received. Hence to neutralise $62 \cdot 8$ mic. we require S such that—

$$62 \cdot 8 \times S = 31 \text{ (LS of B tune)}$$
$$\text{or } S = \cdot 494 \text{ kilo-centimetres,}$$

the same answer as by 1st method.

Example III.

Suppose in Example II. we wish for some reason to add another inductance (say $62 \cdot 8$ mic.) into the circuit—

We can neutralise this $62 \cdot 8$ mic. in two ways:—

1*st Method.*

Our *surplus* is now $62 \cdot 8$ mic. + $62 \cdot 8$ mic., hence our new value **for S is—**

$$S = \frac{31}{2 \times 62 \cdot 8} = \frac{\cdot 494}{2} = \cdot 247.$$

2*nd Method.*

Assuming we had already made $S = \cdot 494$ and thereby caused neutralisation, and we now introduce the $62 \cdot 8$ mic. without touching $S = \cdot 494$ we must of course bring in a new condenser S_1 such that—

$$62 \cdot 8 \times S_1 = 31$$
$$\text{or } S_1 = \cdot 494$$

hence we again have neutralisation, this time with two condensers S and S_1 each equal to ·494, and as they are in series with each other the result is—

$$\text{Cap.} = \frac{SS_1}{S + S_1} = \cdot 247$$

which is what we found necessary by the first method.

These examples will, it is hoped, explain the theoretical methods of tuning up the aerial with "simple resonance."

The extra conditions required to be fulfilled with "tuned shunts" are given on page 43.

Practical trials have fully confirmed the correctness of the above theory.

Calulation of $\lambda\sigma$ for Aerials.

In the preceding examples the knowledge of the $\lambda\sigma$ of the aerial in use is required.

(*a*) They may be calculated from the following formulæ:—

$$\text{Single aerial} \quad L = \cdot 061\, l\,(2 \cdot 3 \log. \frac{4\,l}{d} - 1 \cdot 5)$$

$$\text{Double aerial} \quad L = \cdot 061\, l\,(2 \cdot 3 \log. \frac{4\,l}{\sqrt{2\,bd}} - 1 \cdot 5)$$

$$\text{Fourfold aerial} \quad L = \cdot 061\, l\,(2 \cdot 3 \log. \frac{4\,l}{\sqrt[4]{11 \cdot 3\, b^3\, d}} - 1 \cdot 5).$$

In these formulæ:—

l = length in feet.
d = diameter in feet.
b = distance between wires in feet. (In case of fourfold b is distance between two of the adjacent wires assumed to be forming a square.)
L = actual inductance of the whole wire of length l measured in micro-henries (defined as the "flux per unit of current").

When any of the above are used as simple aerials, the virtual inductance—

$$\lambda \text{ is } = \cdot 406 \text{ L micro-henries}$$

and the capacity—

$$\sigma \text{ is } = \frac{9 \cdot 3}{10^4} \frac{l^2}{L} \text{ kilo-centimetres}$$

(here l is measured in feet).

NOTE.—The virtual inductance "λ" of an *aerial* is not the same as the inductance "L" of the whole *wire* composing the aerial; but is always less than it in practice. (*See* A R, 1903, page 112.)

λ would equal L if the current travelled right up to the top of the aerial before branching off through the air back into the earth; thus in the case of a roof aerial with a very large overhead capacity almost all the current would reach the top, and therefore λ would nearly equal L; whilst in the case of simple aerial, the capacity is distributed all along the wire; hence the mean height of the capacity is roughly half the total height of the wire; and therefore λ is roughly a half of L. Theory shows $\lambda = \cdot 406$ L for a simple aerial, and on page 34, we give an expression for getting "λ" for a roof aerial.

It is interesting to note that in this expression the terms outside the brackets, which are far the most important, are derivable by considering the roof aerial as a lever with its fulcrum on the earth and with the capacities as the weights distributed at distances proportional to the inductances; whilst the balancing capacity is the sum of the weights (capacities) and acts at a distance "λ" from the fulcrum when in equilibrium.

The following numbers are calculated from these formulæ:—

Single Marconi bare Aerial (d = ·012 feet).

Length l in Feet.	L per Foot.	L.	λ per Foot.	λ.	σ per Foot.	σ.
10	·403	4·03	·164	1·64	·00231	·023
100	·544	54·4	·221	22·1	·00171	·171
200	·585	117·0	·238	47·6	·00159	·318
300	·611	183·3	·248	74·4	·00153	·459
400	·629	251·6	·256	102·4	·00148	·592

Double Marconi bare Aerial (b = 10 feet).

Length.	L per Foot.	L.	λ per Foot.	λ.	σ per Foot.	σ.
100	·318	31·8	·129	12·9	·00292	·292
200	·359	71·8	·146	29·2	·00259	·518
300	·385	115·5	·156	46·9	·00242	·726
400	·403	161·2	·164	65·5	·00231	·924

In using the numbers "per foot" we must take them from an aerial of roughly the same length.

Thus, suppose we wish to get σ for a 240-foot single aerial:—

σ per foot for 200 feet Æ = ·00159
„ „ 300 „ „ = ·00153

And therefore for a 250 feet Æ σ per foot = mean of above = ·00156
or σ of 240 feet Æ = ·00156 × 240 kilo-cm.

Example.—Simple Aerials.

What is λ σ of 180 feet double aerial—

From table taking values for 200 feet.
λ = ·146 per foot × 180 feet
= 26·3 micro-henries.
σ = ·00259 per foot × 180 feet
= ·466 kilo-centimetres.

(*b*) *To get the λ σ of Roof Aerials.*

First get the capacity by adding that of the roof to that of the feeder.

Example.

Roof single wire 150 feet long overall—

$$\sigma = \cdot 00164 \times 150 = \cdot 246 = S_1$$

Feeder single wire 180 feet long—

$$\sigma = \cdot 00162 \times 180 = \cdot 293 = S_2$$

$$\text{Total } \sigma \text{ for roof Æ} = \cdot 539 = S_1 + S_2.$$

Then to get the λ for this aerial we must use the following formulæ:—

$$\lambda = \frac{\cdot 406\, S_2 + S_1}{S_1 + S_2} \times L \times \left(\frac{1 \pm \sqrt{1 - \dfrac{S_1 S_2}{(\cdot 406\, S_2 + S_1)^2}}}{2} \right)$$

$$= 0\cdot 677 \times L \times (0\cdot 84 \text{ [or } 0\cdot 161\text{]}).$$

(The larger value (0·84) of the expression inside the bracket must always be used. The other value (·161) expresses the other LS value of the double system of wires which constitute the "roof Æ.")

And L = inductance of whole feeder
= ·58 per foot × 180
= 104
∴ λ = 0·677 × 104 × 0·84
= 59·4 micro-henries.

By comparing these results with those given on page 55, it will be seen what kind of reliance can be placed on the calculations. In a sea-going ship the wire stays would probably add to their capacity; consequently practical measurements are always to be preferred, at any rate until further experience is gained afloat of the effects of shielding; at the same time suitable instruments for making these measurements will not be generally available for some time, and therefore the calculated values must be used as an approximation for the present.

The Calculation of Induction.

The self-induction of a coil or tuner can be calculated from Lieut. Yeats-Brown's curve given in Plate VI.

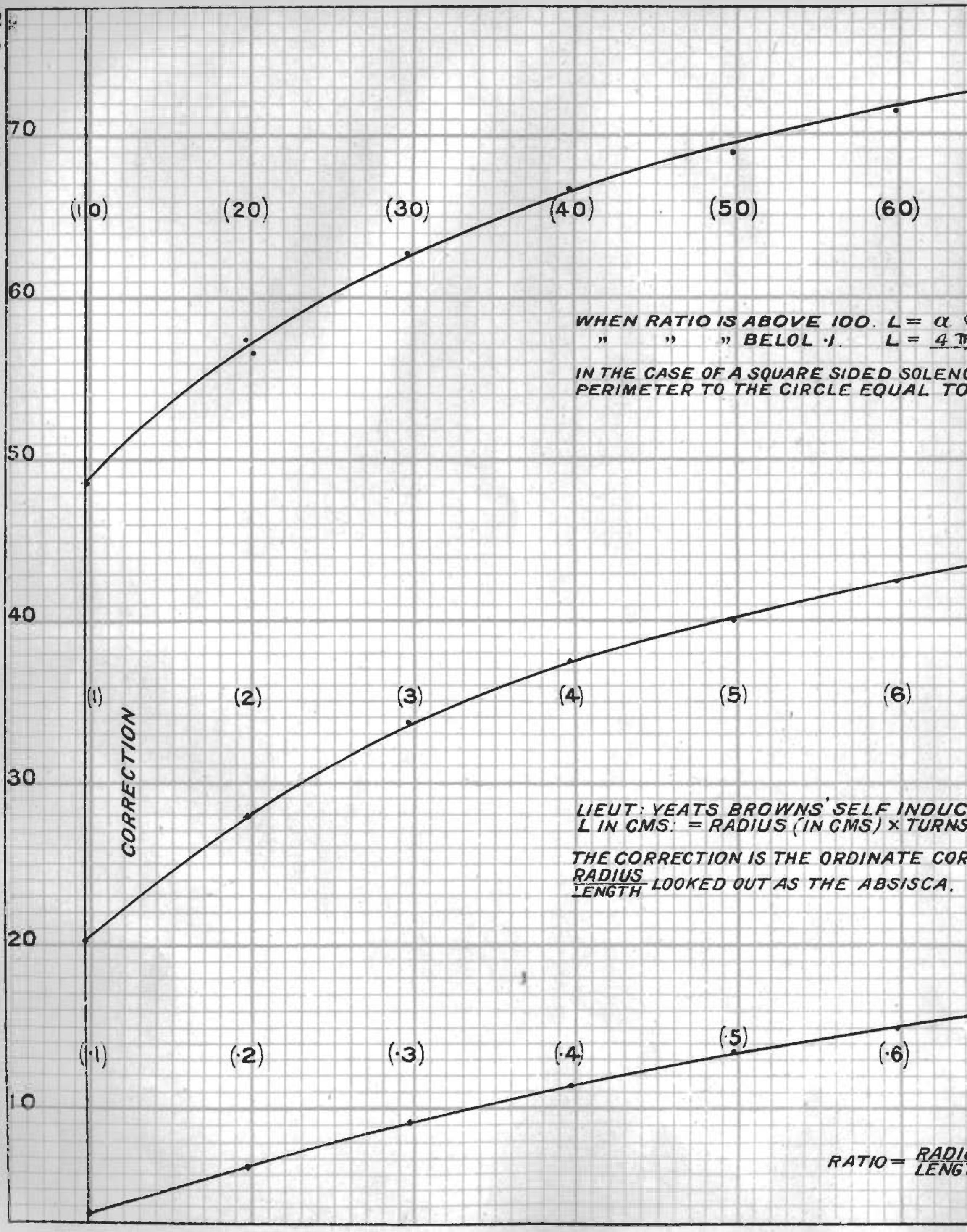
Two measurements are required:—

(*a*) The radius of the coil in centimeters (if the wire is thick the mean radius of a turn should be taken); and

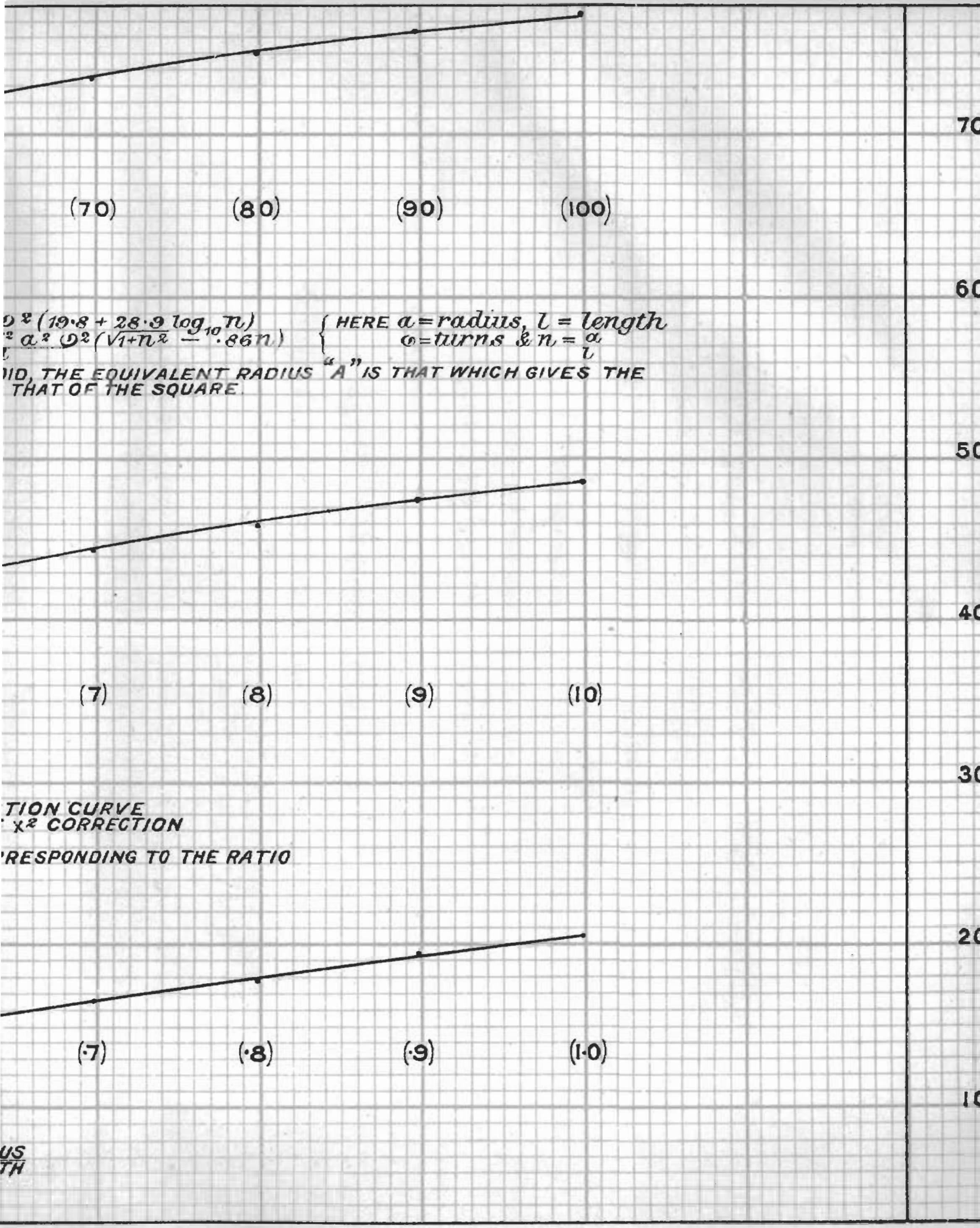
(*b*) The axial length of the winding in centimeters.

Example 1.—To find the self-induction of a coil consisting of 20 turns of pattern 511, close wound on a circular former of 3 inches diameter.

To face page 34.



Weller & Graham, Ltd. Litho London.



A.R.'04

W.T. Section

Plate VI.

The outside diameter of the coil is 3½ inches, and therefore the mean radius is 1 inches or 4·13 cms., *i.e.*, a = 4·13.

The measured length of the winding 11·7 cms., *i.e.*, l=11·7 and the ratio $n = \frac{a}{l} = \cdot 353$.

From the curve the correction corresponding to this ratio is 10·3.

Then the self-induction of the coil is—

$$a \times (\text{turn})^2 \times \text{correction}.$$
$$= 4\cdot 13 \times 400 \times 10\cdot 3.$$
$$= 17{,}050 \text{ cms.}$$
$$= 17\cdot 05 \text{ micro-henries.}$$

Example 2.—Required the self-induction of 10 turns of a tuner, 1 foot square the axial length of the 10 turns being 2 inches.

The length of one turn is 4 feet and the radius of a circle with this perimeter is—

$$\frac{4 \times 12}{2 \times \pi} = 7\cdot 64 \text{ inches} = 19\cdot 4 \text{ cms.}$$

Thus $a = 19\cdot 4$, l (2 inches) $= 5\cdot 08$.

$$\text{and } n = \frac{19\cdot 4}{5\cdot 08} = 3\cdot 82.$$

Then from the curve the corresponding correction is 36·7 and thus the self-induction is—

$$19\cdot 4 \times 10^2 \times 36\cdot 7.$$
$$= 71{,}200 \text{ cms.}$$
$$= 71\cdot 2 \text{ micro-henries.}$$

The following table gives the induction of various tuners used in service :—

No. of Turns.	Self-Induction in Micro-Henries.			
	Tuner.			
	A.	B.	C.	D.
5	22·5	35	16·5	6·1
10	72	115	48·5	17·5
15	—	—	92·5	30·5
20	211	355	140·	44·0
30	402	672	—	—
40	625	1,032	—	—
50	867	1,440	—	—
60	1,130	1,870	—	—

A is the Service tuner, former one foot square, wound with bare wire five turns per inch.

B a Marconi tuner, former 18 inches square, wound with insulated wire closely packed.

C a Marconi tuner, former one foot square, wound with bare wire two turns per inch.

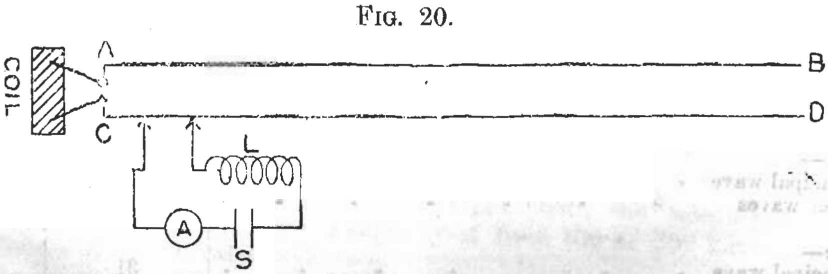
D a tuner, former 6 inches square, wound with bare wire two turns per inch.

Calibration of Laboratory Apparatus and Standards for Measurement of L, S, and LS.

Standard Wavemeter.

The importance of having some standard for wave lengths was early recognised, and the following method of making one was finally adopted :—

Fig. 20.



Two pieces of bare Marconi aerial AB, CD, were stretched parallel to each other, about one foot apart, and suspended by insulators on main deck of "Hector."

An auxiliary circuit LS was adjusted to resonance by variation of the capacity S (which consisted of an adjustable air vane capacity made to our designs by Messrs. Muirhead & Co.).

And we *assumed* that (as a consequence of theory) the wave length of the sending circuit was equal to four times the length AB.

The self-induction L in the auxiliary circuit having been calculated (the self-inductance of the connecting wires was made as small as possible, and was measured for three different values of S by comparison with the calculated inductances), and the wave length of the sender being taken as four times AB, gave the value of the capacity S for that position of the pointer attached to the adjustable vanes.

Putting in another inductance L_1 gave a new capacity S_1 for resonance; and this process was repeated until a curve of capacity for various positions of the pointer could be drawn.

Next AB was shortened so as to give off another wave length, and the above processes being repeated, gave a second capacity curve.

This was repeated several times, and the resulting capacity curves being found to approximately coincide, it proved :—

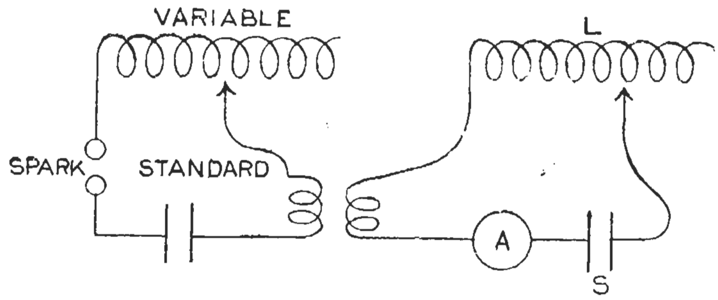
(1) The wave length given off *is* very approximately proportional to four times AB ;

(2) The formulæ for L (which are taken from Lieutenant Yeats-Brown's curve) are very approximately correct.

Knowing, therefore, that the capacity and inductance were approximately correct in reproducible units, any given wave length can now be measured by putting in a suitable inductance and turning the pointer of the capacity to the required point.

From this standard an auxiliary sparking standard has been calibrated, and besides being used for measuring wave lengths, it is employed for the measurement of self-induction and capacity by obtaining resonance between two circuits.

FIG. 21.



In the right-hand circuit either L or S must be known ; (suppose L is known) then as we also know the LS value of the standard we can calculate the value of S.

Similarly if S is known, L can be calculated.

For the purpose of getting *definite* results in Wireless experiments, it is of the *utmost* importance to be able to rapidly and readily alter the inductance and capacity of the various circuits in use.

Many months were therefore spent in designing suitable apparatus and in calibrating it after it had been made, with the result that "Vernon" now has a set of variable inductances and capacities, and is probably as well equipped for carrying out experiments in Wireless as any laboratory.

The variable inductances may possibly be introduced into the Service, and are of the "Ayrton and Perry" type, the principle of which consists in winding an equal number of turns of wire on two formers, one of which is free to revolve inside the other. The turns are all placed in series, and in one position the lines of force through the inner coil act in opposition to the lines through the outer; consequently the bobbins are "non-inductively" wound, whilst as the inner bobbin is turned round so do the bobbins become more and more "inductively" wound to each other. The inductance, of course, varies accordingly to the line of force; and in practice with the present construction the maximum value of the inductance of a given set of turns is about five times the minimum value, so that a considerable range is secured.

A standard air condenser is now being obtained which will enable our units to be checked in absolute measure.

Result of Actual Measurements of Wave Lengths.

—	L.S. Value.	Wave Length.
Tune A:—		Feet.
Principal wave	3·7	395
Other waves	2·0 and 75	290 and 1,800
Tune B:—		
Principal wave	31	1,150
Other wave	58	1,570
*Longer wave used by "Boscawen II."	240	3,200
Chelmsford—Principal wave	280	3,450
Poldhu (present wave Nov. 1904) principal wave	950	6,350
Other wave	750	5,650

* This is a plain aerial wave, obtained by placing inductance at the bottom of a roof aerial. The results given on pages 44 and 45, are with this wave, which is a very persistent wave without any subsidiary waves.