MAGNETIC NO-LOAD RELEASE KEY.

Magnetic key.

Experiments have been made with this key.

When used with direct current and a pair of coils connected in series, it works very smoothly and easily, with practically no sparking or wear at the contacts.

When used with an alternating current of 25 ampères, it also worked well, but there was a decided decrease in the maximum spark obtainable. These experiments have only been possible with coils used as transformers, and the decrease in spark length may not be serious when a slightly modified key is used with a proper transformer.

The key was carefully adjusted, and its self-induction measured with different currents :—

Current.	Self-induction.
7·3 ampères	·0142 henries.
16·0 „	·0108 „
25·1 „	·0025 „

So that the key has considerable self-induction which varies widely with the current, showing that the iron in the key must become saturated at about 15 ampères. If this key were placed in the primary of the circuit proposed for "C" tune it would be equivalent to adding $\cdot 0078 \times \left(\frac{7500}{70}\right)^2 = 89\frac{1}{2}$ henries to the secondary (*see* alternating current on coil, page 52, 70 and 7,500 being the proposed primary and secondary volts respectively). This induction would increase to 160 henries for smaller currents. The total self-induction in the secondary for resonance is only 220 henries, so that the varying inductance due to the key would seriously disturb the resonance effects, and must be the cause of the reduced spark length.

When working with 20 ampères, the total loss in the key is about 30 watts, which is quite small, and would probably have no perceptible effect on spark length.

TRIAL OF ELECTROLYTIC CONDENSERS TO REDUCE SPARKING AT KEY.

As an alternative to the magnetic key an electrolytic condenser was tried across an ordinary key.

A cell made up with aluminium as one plate, and some other metal—iron, for instance—as the other, with an electrolyte of a 15 per cent. solution of phosphate of ammonia, possesses peculiar rectifying effects. When the aluminium is made the cathode, current will pass freely through the cell, entering through the iron. When the aluminium is made the anode, however, it is instantly covered with an infinitesimally thin layer of aluminium oxide, which is an excellent insulator. This insulating layer will stand from 80 to 100 volts without perforating, but is broken up with about 150 volts. These cells are often used for rectifying alternating current.

They possess a second useful property. The layer of aluminium oxide is an excellent dielectric, so that the cell forms a condenser, the aluminium sheet being one plate and the electrolyte the other, the layer of oxide being the dielectric. The latter is so very thin that a large capacity is obtained with a very small surface (about 20 to 25 jars for each square cm. of oxide). If both electrodes are of aluminium, a condenser is formed which will work with an alternating current; the condenser being formed between one plate and the liquid when the current is in one direction, and between the other plate and the liquid when the current is in the other direction.

A small condenser of capacity about one third microfarad, 13 square cm. plates, was tried in parallel with a key working on direct current, 100 volts; it worked well and absolutely stopped all sparking. When the condenser was disconnected, an arc invariably formed on lifting the key.

Another condenser of about 8 microfarads was tried across the key used with the improvised "C" tune used in the "Vernon." This key carried about 30 ampères at 100 volts alternating. Although when the condenser was disconnected the key worked fairly well (no arc forming, but only a little sparking), the addition of the condenser made no practical difference to the sparking

An arrangement was then tried which automatically partially destroyed the film of oxide when the key was "made," allowing it to be reformed after the key was broken; this did not work well, and was rather clumsy. A condenser of ten times the capacity of that used would probably be practical. Experiments with this arrangement and with the magnetic key are being continued.

EXPERIMENTS WITH ALTERNATING CURRENT ON COILS.

Alternating current applied to coils.

The following experiments were made to find out if the coils supplied for wireless telegraphy are suitable for use with alternating current.

A small rotary converter which would give 10 ampères at 64 volts alternating when supplied with direct current at 100 volts, was tried.

Applying 100 volts direct current and connecting the 64 volts alternating to a 1904 pattern induction coil, the coil took 7 ampères, when supplying no energy; and sparking started at the commutator.

Thus 70 per cent. of the full-load current of the rotary converter is wasted in the coil before the latter begins to supply energy, and the commutation is disturbed by the "lagging" current then taken.

If supplying a properly designed transformer and choking coil, giving a 50 per cent. efficiency, this converter would give a 1-cm. spark on 30 jars at 20 words a minute without any strain.

An older pattern coil was then tried with worse results; 12 ampères were wasted in the coil and the sparking at the commutator was very bad. The magnetic circuit of the first coil was then closed, a return path for the magnetic lines from the ends of the coil being made with thin iron sheets; this improved matters. The applied direct voltage was decreased to 80 volts. The no-load current taken by the coil was reduced from 7 to 4 ampères, and there was no sparking at the commutator. When a second coil was used as a choking coil and connected to 16 jars, an indifferent spark of 8·5 mm. was obtainable. But this compares very badly with the rapid signalling spark of 8 mm. on 30 jars that would be possible with this applied voltage if a transformer and choking coil were used.

Using a larger rotary converter the following results were obtained on 16 jars, using one coil as transformer and another as resonator:—

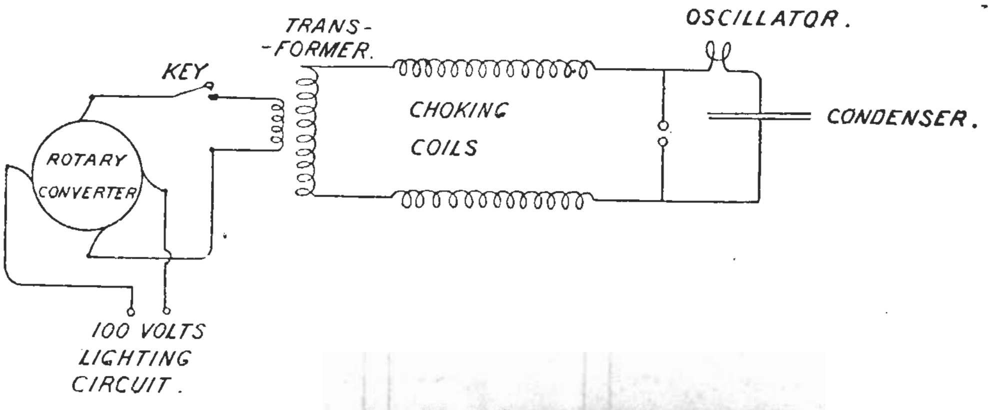
Applied Direct Current Volts.	Coil used as Transformer.	Magnetic Circuit of Coil.	Maximum Spark in mm.	Alternating Current.*	No-load Current Waste in Transformer.
88	1904 pattern -	Closed - -	10·5	12·5	4·8
75-80	„ -	Open - -	8·0	10·0	6·2
95	„ -	„ - -	10·0	12·5	8·2
75-80	Older pattern -	„ - -	10·0	16·0	11·8

* This is the current taken when making a "dash."

In every case the no-load waste current is a large percentage of the total current taken when working at maximum power. Also this waste current lags, and is, therefore, especially harmful.

The connections for the above experiments were as in Fig. 18. The best frequency being about 29 periods per second for the coils with open magnetic circuit; this frequency corresponds to 1,740 revolutions of a two-pole and 870 revolutions of a four-pole rotary converter.

FIG. 18.



Experiments have been made with different combinations of coils to excite the improvised "C" tune that has been used. Using a 2½ K.W. rotary, two coils and two old coil primaries, a 20-mm. spark on 15 jars, a 10-mm. spark on 60 jars, and a 7-mm. spark on 120 jars have been obtained; all corresponding to the same power.

The last arrangement was used with the "C" tune experiments during September 1905.

These makeshift arrangements, however, put a great strain on both the coils and the rotary converter; it is necessary to stop to allow coils, &c., to cool down after sending for about 15 minutes, and it is not possible to get a "long" of more than about two seconds' duration.

Although with 15 jars it is possible to get better results with an alternating current than with direct, a coil is not suitable for alternating current work. With a transformer and choking coil the efficiency is more than doubled, and therefore the rotary converter can be halved in power. Also a transformer and choking coil to give 1-cm. spark on 160 jars at 20 words per minute would occupy about the same space as three coils, and at least eight coils would be necessary for this output.

THEORY.

Coupling.

Coupling.

When two resonating circuits are linked together by mutual inductance their mutual action is determined by the relative amount of mutual inductance between them.

When it is great the two circuits are said to be "tightly coupled," and when small "loosely coupled," or sometimes "lightly coupled."

Take l_1 as the self-induction of the first circuit, or the number of lines threading through the circuit when a unit current flows through it.

And l_2 the self-induction of the second circuit.

Also m as the mutual induction between the circuits, or number of lines that thread through the first circuit when a unit current flows through the second. This is also equal to the number of lines which thread through the second circuit when a unit current flows through the first.

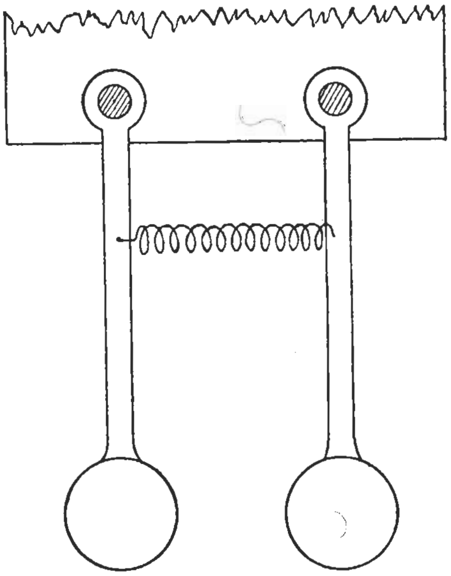
If there is an alternating current in the first circuit the back e.m.f. across its inductance will be $l_1 \times$ rate of change of current $\left(\frac{d\,c}{d\,t}\right)$ and the back e.m.f. in the second due to the current in the first is $m \times \frac{d\,c}{d\,t}$. So that the greater m is, the greater is the e.m.f. in the second circuit.

The greater l_2 is, however, the smaller is the effect of a given e.m.f. on the second circuit. Thus, $\frac{m}{l_2}$ is a measure of the grip the first circuit has on the other.

The ratio $\frac{m^2}{l_1\,l_2}$ has been adopted as a measure of the mutual reaction between the two circuits, and is called the "coupling."

When the two circuits are very close together and every line of force passing through the primary also passes through the secondary, the coupling is 1, its maximum value. The two circuits are rigidly connected together and may be represented by two pendulums connected by a rigid connecting rod. As the circuits are taken further apart the coupling factor becomes smaller and the coupling looser, until when the circuits are a great distance apart they have no mutual action, and the coupling factor is zero. A tight coupling would be represented by a strong spring connection between the two pendulums, and a loose coupling by a weak spring as in Fig. 19.

FIG. 19



When one circuit (or pendulum) is started oscillating, the other will pick up the oscillations rapidly if the coupling is tight, slowly if it is loose. When the coupling is loose, and therefore the spring weak, the second circuit will only oscillate slowly if the two circuits are accurately in tune. When the coupling is tight the tuning will make much less difference.

Consider the first circuit to consist of the primary of an oscillator with sending condenser and spark-gap, and the second circuit of the secondary of the oscillator and attached aerial. When the coupling is tight the energy from the primary will pass rapidly into the aerials which will be charged to the highest possible potential and radiate rapidly, the result being a few strong oscillations.

When the coupling is loose, however, the energy will pass slowly into the aerial, which will radiate slowly.

The potential of the aerial will never become very great, as the full energy will not reach the aerial until the greater part of it has been radiated away. The result is a well-sustained train of weak oscillations.

The above is only an approximation to the true state of affairs, which is more complicated. Theoretically there is a continual interchange of energy between the primary and secondary, it being more rapid with a tight coupling.

When two loosely coupled circuits are in tune the whole energy slowly passes from the primary to the secondary, and then the part that has not been radiated or wasted there slowly returns to the primary, to be again passed on to the secondary. The radiated energy in this case is equally divided between the two principal waves. When the two circuits are out of tune only a portion of the energy passes back and fore. A certain percentage of the energy in the two circuits at any moment is always in the primary, and there is more of the total energy in one of the principal waves than in the other.

If the primary has the smaller resonance constant, the shorter wave is more pronounced in some cases, and probably in all.

With tight couplings these effects are not as marked.

When the aerial is large, as in shore stations, a tight coupling is most efficient. But when, as in ships, the size of the aerial is strictly limited, looser coupling must be employed if large power is necessary; for instance, the coupling with "C" tune, with $2\frac{1}{2}$ K.W. power, will be comparatively loose. With "B" tune, where the radiated power seldom exceeds 0·1 K.W., the coupling can be tight.

With tight coupling, the principal loss of energy is in the aerial, and is due to resistance in the earth connections, oscillator, &c.; to bad insulation of the aerial and brushing, which gets bad, and a source of considerable loss when the potential of the aerial exceeds a critical value, depending on its shape and distance from the earthed objects.

With loose coupling the principal losses occur in the primary. They are due to resistance in the leads and spark-gap, and hysteresis of condensers.

The best value of the coupling is also modified by external conditions. It is probable that a long train of well-tuned waves travels more efficiently, especially overland, than a few strong waves.

A loose coupling appears to suit the electrolytic coherer, a medium one the magnetic detector, and a tight one the ordinary coherer.

If a fair power is used, a tight coupling means a great strain on all insulation, which must be much heavier, especially in the deck tube and oscillator.

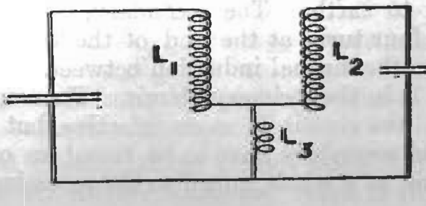
A loose coupling is better for tuning, causes less interference with other tunes, and allows sharper tuning at the receiving end.

The relative value of the two principal waves is also governed by the coupling, two waves of nearly equal length being possible only with a loose coupling.

If the two circuits are in tune their resonance constant being $l\,s$, the constants of the two waves will be theoretically $l\,s\,(1 + \sqrt{C})$ and $l\,s\,(1 - \sqrt{C})$ where C stands for $\frac{m^2}{l_1\,l_2}$ the coupling. If the two circuits are not in tune the difference between the two waves will be greater.

Two circuits may also be coupled together by arranging them so that they have part of their inductance in common, as in Fig. 20.

FIG. 20.



Here the total self-induction in the first circuit $l_1 = L_1 + L_3$, self-induction in the second circuit $l_2 = L_2 + L_3$ and for all practical purposes they are linked together in exactly the same way as if they were quite separate, but had a mutual induction $m = L_3$.

For experiments to determine the best coupling for "C" tune, *see* page 33. These experiments would have been better if they had included some tighter couplings; these were not possible, however, as the strain on the deck tube would have been too great.

The coupling of a transmitting circuit is a fixed quantity, not easily varied, which is definitely settled when the oscillator is designed.

The coupling of a receiving circuit is an easily varied quantity, and the theory of its working may be of considerable practical use.

The effect of varying the coupling at the receiving end is similar to that at the transmitting end, but a little more complicated on account of tuning effects.

In receiving circuits there are in general two distinct operations in tuning up. Firstly, the different parts of the circuit must be in tune *with one another* so that they will work together. Thus for best effects the primary of a jigger and the aerial form a circuit which should have the same resonance constant as the secondary circuit with the coherer attached; and when using a tuned shunt, the rejector, acceptor, and aerial circuit should all be in tune with one another and have the same resonance constant. Getting the different parts of the receiving circuit into tune with one another may be called "*self-tuning*" the circuit.

Secondly, the receiving circuit as a whole must be in tune with the transmitting circuit, so that it will respond to one of the waves given out by the latter. For best effects one of the principal waves of the receiving circuit, that is, one of the waves with which it would oscillate if given an impulsive blow, must be the same as the wave it is desired to receive. Getting the transmitting and receiving circuits into tune with one another may be called "*mutual tuning.*"

In general, when an adjustment is made in the receiving circuit, it affects both self and mutual tuning, and if self-tuning, say, is made more perfect by the adjustment, it is possible that mutual tuning is made less perfect, so that in receiving circuits it is always well to make small final adjustments for tuning after everything is apparently in tune, and signals may often be improved by so doing. In some cases, one of the tunings will be much more pronounced than the other and tend to conceal it, and final adjustments become more important and more difficult.

It appears that a loose coupling in the receiving circuit means that self-tuning is more pronounced, and a loose coupling in the transmitter that mutual tuning is the more pronounced. Also that damping and loss of energy in the receiving instruments increases the importance of self-tuning.

If mutual tuning is good, the radiated energy will be easily absorbed by the receiving circuit, and if self-tuning is good, this energy will be readily conveyed from the aerial to the receiving instrument.

If a loose coupling is used in the receiving circuit the reception will be selective, that is, the receiver will only respond slightly to interference, differing in wave length from the signals to which it is tuned, but the circuit will require careful management. A receiving circuit with tight coupling will be more liable to interference, especially so, as its two principal wave lengths are fairly different (the formula given above for transmitting circuits), and it will respond to interference of a wide range of wave lengths.

Imperfect tuning, bad contacts, defective insulation, and faulty connections will have much more effect when a loose coupling is used than when a tight coupling is used, and the former will probably only give very inferior results in the hands of unskilled operators, but every selective receiving device must suffer from the same defect, as to be selective a circuit must have sharp tuning, and can therefore only be efficient if properly looked after.

When receiving by simple resonance, the full aerial current passes through the receiving instrument, the coupling between aerial and receiver is the tightest possible, and the arrangement is only slightly selective. (In this case the primary and secondary are one and the same circuit, and there is no self-tuning.)

When receiving by the Marconi method of cutting out atmospherics with the magnetic detector, there are two distinct circuits. The primary circuit, down the aerial, through the tuner to earth. The secondary, through the condenser, magnetic detector, and the three or four turns at the end of the tuner. The coupling between the two circuits depends on the mutual induction between these three or four turns and the rest of the tuner that is in the primary circuit. The coupling is now looser than with simple resonance, and the circuit is more selective, but the tuning is more complicated. The primary and secondary have to be tuned to one another, *i.e.*, the circuit self-tuned; and the circuit, as a whole, tuned to the incoming signals. The capacity of the condenser, and the number of turns of tuner in the aerial circuit, have both to be varied, an alteration in one generally meaning a small alteration in the other. The smaller the number of turns of tuner in the secondary or magnetic detector circuit, the smaller the mutual induction between the two parts of the circuit; the looser the coupling, the sharper the tuning, and the greater the selectiveness of the receiving arrangement.

With tuned shunts there are three distinct circuits, the aerial and tuner, the acceptor, and the rejector. The self and mutual tuning are reduced to getting each circuit into resonance with the wave to be received. The coupling depends entirely on the rejector; the larger the capacity in the rejector, the looser the coupling and the sharper the tuning.

The selectiveness of this arrangement is largely due to the fact that the coupling is different for different wave lengths, it is much greater for the wave length to which the rejector is tuned than for any other. The more a disturbing wave differs from the wave to which the rejector is tuned, the looser the coupling for it; and, as the circuit is not in tune with it, the smaller its effect on the receiver. By increasing the size of the rejector capacity, the coupling for the wave to which the circuit is tuned becomes fairly loose, and therefore the coupling for any jamming wave of a fairly different wave length very loose. For a wave of very different wave length the coupling would be very small indeed.

Theoretically, there is one principal wave to which a tuned shunt receiving circuit will respond, and two other waves, one a little longer, and the other a little shorter than the principal wave. To these subsidiary waves the circuit should respond less readily. They have not been found by experiment, at present, but they are only likely to allow interference from sources differing but very little in wave length from the principal wave, which the circuit is tuned to receive.