VENTILATION OF WIRELESS OFFICES AND SILENT CABINETS.

The necessity for better ventilation of Wireless Telegraphy Offices and Silent Cabinets has been much felt, and was specially referred to during the Conference of Wireless Telegraphy Experts. (*See* page 9.)

In order to ascertain the best method of improving the ventilation, exhaustive experiments were carried out in "Vernon." The results of the experiments have been reported to the Admiralty, together with certain proposals for improving the ventilation. These proposals are briefly summarised below.

PROPOSALS FOR IMPROVING THE VENTILATION.

(*a*) To use the circulator as a supply fan, supplying fresh air from the upper deck to the *bottom* of the silent cabinet, and leaving the exhaust at the top of the cabinet to work as a natural exhaust into the office. The supply of air from outside is considered to be of vital importance, and the use of the circulator as a supply is recommended, because, if the silent cabinet is not absolutely airtight, a circulator acting as an exhaust will probably draw foul air from the office into the cabinet, instead of fresh air from the upper deck.

(*b*) To supply a proper exhaust from the wireless office—the exhaust to be in the roof.

The provision of an efficient exhaust to the office is considered to be of at least equal importance to the arrangements for supply.

(*c*) To render the cabinet properly airtight in order to ensure proper circulation of fresh air, and also to improve its sound-proof qualities.

(*d*) To reduce the number of baffles on the top and bottom of cabinet, and remove other obstructions in the air passages. Experiments show that the number of baffles can be reduced without seriously affecting the sound-proof qualities of the cabinet.

(*e*) To place the circulator regulator inside the silent cabinet.

(*f*) To supply a larger circulator in new ships and to all ships on foreign stations where hot weather is experienced.

The alterations to silent cabinets can be effected very easily, and detailed instructions as regards this work will probably be issued shortly.

EXTRACTS FROM A REPORT ON WIRELESS TELEGRAPHY EXPERIMENTS CARRIED OUT BETWEEN "VERNON" AND "FURIOUS," MAY-JUNE 1910.

I.—Experiments to obtain a higher Musical Note with Mark II. Sets.

The object of these experiments was to obtain a 700-cycle note from the Mark II. installation, the higher note being easier to read over atmospheric disturbances.

From the results it appears that the condition for obtaining the double note, *i.e.*, obtaining two sparks per cycle of supply voltage, are much more critical and unstable than those necessary to obtain regular sparking once per cycle, and, although some fairly good results were obtained, the double note produced was not sufficiently reliable for its use at sea to be recommended at present.

Three methods were tried, viz.:—

(a) *Using an Auto-transformer.*—This method did not give satisfactory results.

(b) *Cutting the Impedance Coil out of the Circuit.*—This method gives a good double note when the Mark II. condensers are in series, as used for "Q" and "R" waves, but with the condensers in parallel, as used for longer wave-lengths, does not give a very reliable note.

The current taken with the impedance coil short circuited is rather large, necessitating the disconnecting of the A.C. ammeter; and the magnetic key is liable to give trouble with this arrangement unless very carefully adjusted.

(c) *Shortening the Spark Gap and raising the applied Volts.*—This method worked fairly reliably, but the conditions for obtaining the double note were found to be very critical.

It would appear that method (*b*) is the most suitable when the series arrangement of transmitting condensers is in use, and that method (*c*) is the best with the condensers in parallel.

The best results actually obtained were with the following arrangements:—

Method (*b*)—Condensers in series:	Method (*c*)—Condensers in parallel:
Supply {350 cycles. 460 volts.	Supply {350 cycles. 460 volts.
Impedance coil short-circuited.	Impedance coil in circuit.
12 mm. spark.	6 mm. spark.

With these arrangements it appears that a fairly reliable double note can be obtained with a very slight reduction in range, due to the shorter spark length used. The reduction in strength is very small, and is probably counterbalanced by the more penetrating character of the higher note.

However, it will be necessary to carry out further trials before this method can be considered entirely reliable, and, in view of the difficulties mentioned above as attaching to method (*b*), the use of the double note at sea is not recommended at present.

New form of Spark Plug.

Various forms of spark plugs were tried during the experiments described above.

The most satisfactory results were obtained by using a new form of spark plug in the shape of a wedge, with its vertical edge as the sparking point. Further trials will be made with this form of plug.

II.—Trials of improved Revolving Spark Gap (as recommended by H.M.S. "Suffolk") in Mark I*. Installation.

The type of spark gap recommended by H.M.S. "Suffolk" has been constructed in "Vernon," and was tried with the Mark I*. installation.

The spark gap has worked very satisfactorily. When using this gap the ordinary note transmitted by Mark I*. is obtainable with very slow speed of revolution, and, if desired, very high notes can be obtained without excessive speed of the auxiliary motor.

III.—Experiments with Quenched Spark Sets.

Two extemporised sets were used during the trials with "Furious"; these are referred to below as the large and small sets.

Very promising results were obtained, though the present form of spark gap for these sets is not very reliable.

The efficiency of transmission appears to be considerably higher, and the instruments are lighter, cheaper, and smaller, than is the case with the ordinary spark installation.

If, as is anticipated, the gap difficulty can be got over, it is considered that the system will probably prove suitable for introduction into the Service, the small set appearing to be particularly suitable for use in the naval airships.

Various types of gap were tried with a view to obtaining one which will remain in adjustment without attention, but these gaps, hastily constructed and altered as suggested by experience gained during the programme, were in no case well finished articles, and did not prove reliable. A new form of gap is now under construction, and trials will be continued.

Details of Results obtained with the two sets are given below.

(a) *Large Set.*—In the case of the large set, three gaps are used in series, primary condenser is about 350 jars, and the power taken about 5 to 6 kw. on a prolonged " long " and about 3·5 to 4 kw. under ordinary signalling conditions. From the results obtained it would appear that when the gaps are working correctly, reliable communication can be obtained at 350 miles by day.

The results obtained are given below.

Date.	Distance.	Strength.
12.5.10 - - - - -	100	10
19.5.10 - - - - -	300	6
25.5.10 - - - - -	340	6

Signals have frequently been received at Aberdeen (distant 380 miles), strength 8. The reports on the note vary considerably ; this is probably largely due to faults in the spark gap, and with a better gap a material improvement of the note is anticipated.

The set is too unreliable with the present gaps to warrant introduction into the Service, but the results are so promising that trials will be continued, and it is hoped a satisfactory spark gap will be arrived at shortly.

(b) *Small Set.*—The small set consists of two gaps in series, and a primary condenser of about 350 jars. The power taken during a " long " is about 3 kw., the power taken under ordinary signalling conditions being about 2 kw. The small set was designed to send a wave of 590 L.S., but during the programme sent 1,000 L.S.

From the results obtained it would appear that, when the gaps are working correctly, reliable communication can be obtained at 200 miles by day.

The results obtained with this set, using paper gaps, are given below :—

Distance.	Strength.
100 Miles.	6–7
200 „	5
190 „	5

Independently of these trials, communication with Scilly has been maintained with this set, the average strength of signals being 7 ; the distance is about 220 miles.

The set appears to be very suitable for use in the naval airship, the weight being small, the tension low, and the gaps enclosed.

A better spark gap for this set is under construction.

IV.—Airship Spark Set.

This set consists of an ordinary spark installation, the instruments being of a light construction. The 3 kw. 250-cycle alternator designed for this set has not yet been delivered, but a similar power supply was arranged and the rest of the installation was practically complete. The spark gap is fixed at 4 mm. It is found that, under these conditions, arcing takes place at the gap, and a blower of considerable size has to be employed.

When using the blower satisfactory results were obtained, but the extra weight of this blower, and the difficulty of driving it, coupled with the added danger from sparking which must be present with an installation of this type, renders it very questionable whether the set can be made suitable for use in the airship, and it is proposed to improve the small quenched spark set for this purpose, using the same alternator, transformer, &c.

V.—Receiving Detectors.

The " B " type receiving set was in general use in " Furious " and worked very well throughout. In " Vernon " various detectors were tried, and, in particular, further comparisons were made between the crystalite and carborundum-smalltite detectors. There is little difference in sensitiveness between the two, the crystalite detector being, however, slightly better in this respect ; on the other hand, the carborundum-smalltite detector has a slight advantage as regards stability, being not so easily affected by strong signals, atmospherics, &c.

The bornite-zincite detector appears to be better than the Service crystalite detector (ordinary copper pyrites and zincite), remaining longer in adjustment and being easier to readjust.

" Bornite " is a form of copper pyrites which is particularly rich in copper.

Experiments with other stones failed to discover a detector as good as those just mentioned.

VI.—Brown's Relay.

Trials with this instrument in "Furious" and "Vernon" have given very promising results, though the difficulties of adjustment render the instrument in its present form unsuitable for introduction into the Service.

Comparative Trials of Leyden Jars, Schultz Condensers, and Moschicki Condensers.

Trials were carried out to determine, practically, the relative efficiency of the above three types of condensers, with a view to the possibility of superseding the Leyden jar for auxiliary purposes with Mark I*. and Mark II. sets, and for general use in Mark I. sets.

Each type of condenser was used alternately with the same Mark I. set, the same capacity being employed in each case Reports from "Furious" showed that all three types were about equally efficient under ordinary conditions.

The Schultz and Moschicki condensers are mechanically stronger than the Leyden jars, and take up less space for the same capacity.

The Schultz condensers are the strongest of the three.

As regards liability to electrical puncture, the Leyden jars have the advantage in this respect, as they brush over when overcharged, and so are less liable to puncture than the others. Moschicki condensers usually brush over, but occasionally puncture. Schultz condensers could be made equally safe in this respect if fitted with safety spark points.

The results so far are distinctly in favour of the Schultz condenser fitted with safety spark points, but it is not yet known whether these articles deteriorate with use, and it is considered desirable to supply a few sets to sea-going ships for trial before deciding as to their suitability. Before taking further action, however, it is desired to obtain information *re* the manufacture of these articles in England, cost, &c.

QUENCHED SPARK SYSTEM OF W.T.

The Lepel Sets.

Further trials carried out with the Lepel sets, mentioned in W.T. Appendix to Annual Report, 1909, showed that the small set was not suitable for Service work, and that the large power set, as supplied, was of a purely experimental character and quite unsuited for the transmission of signals over anything like the distances claimed for it. However, the results with the large set showed that the principle was sound, and it was therefore decided to construct a set in "Vernon," using this principle, and eliminating, so far as possible, the defects noticed in the Lepel set.

With the new set, which is described in more detail below, very promising results were obtained, though the spark gap was still not satisfactory.

During its earlier trials, this set, when working properly, compared with the Mark II. as follows:—

Advantages—

(*a*) Equal range, using about one-third the power.
(*b*) Greater selectivity, as only one wave is emitted.
(*c*) The smaller size of the installation for a given range.
(*d*) A higher and more penetrating musical note can be obtained.

Disadvantages—

Rapid deterioration and difficulty in adjustment of the spark gap.

In view of these results it was decided to continue the experiments and endeavour to effect further improvement in the design, but as the "Vernon" set had few features in common with the sets purchased from the Lepel W.T. Syndicate, and as the question of the patent rights for the various quenched spark systems was in dispute, it was decided to patent certain of the "Vernon's" improvements and to refer to the experimental set in future merely as the "Quenched Spark Set," so as to avoid any possibility of prejudicing Admiralty claims to the new inventions.

It is recognised, however, that this set is the result of the experiments with the Lepel sets, and that it is based on the same broad principles as those employed by Baron von Lepel. Therefore, in the event of Baron von Lepel establishing his claims to fundamental patents it will be necessary to acknowledge the use of his inventions in the Naval set, and to consider the question of patent royalties.

"Vernon's" Quenched Spark Set.

The principal differences between the sets obtained from Baron von Lepel and the set constructed by "Vernon" have been the alterations in the spark gap, which is the main feature of the system. The Lepel spark gap, or "Generator," is described in W.T. Appendix to Annual Report, 1909, page 41, and consists of flat metal discs separated by a number of sheets of thin note paper, which gradually burn away as the gap is used; the gap is not airtight. The improved spark gap used by "Vernon" is described below, and consists of flat annular metal sparking surfaces separated by permanent insulating material with ample surface insulation. The gap is made airtight and provided with an exterior expansion chamber; it is arranged to allow of a very fine and permanent adjustment of the distance between the sparking surfaces.

A very marked improvement in reliability and in the possibilities of the set is undoubtedly obtainable by keeping the gap absolutely airtight and by providing the expansion chamber.

Other parts of the Lepel apparatus have also had to be discarded and replaced. The mica condensers have been replaced by ebonite ones, the primary connections have been reconstructed to allow more of their inductance to be used for coupling, and in most of the earlier experiments with the "Vernon" set, the oscillator was placed in oil, to reduce brushing between primary and secondary. The set at present employed in "Vernon" has given very promising results as far as range and readiness for work are concerned, but it is not satisfactory as regards note. The quality of the note, and the irregular working that has at times been noted, are undoubtedly due to the faulty design and construction of the spark gaps, and to the experimental and extemporised nature of the rest of the installation.

Considerable difficulty has been experienced in obtaining a spark gap which will work reliably and require but little attention. The latest kind of spark gap, which consists of several elements in series, has been fairly successful, and was in use for seven weeks before it was opened up for examination and cleaning. It was then found that some of the elements were in good condition, and the causes of deterioration of the others were manifest. There is every reason to believe that a properly designed spark gap will stand hard work for two months without cleaning or adjustment, and still be efficient and in thoroughly good order, it is thought very probable that gaps may be used for three or four months or even longer without attention.

In order to ensure satisfactory working the following points amongst others require attention :—

(1) All oxygen must be excluded from the sparking surfaces, otherwise the surface of the copper tends to burn, pimple, and form nodules.
(2) The sparking surfaces must be large and very carefully faced, as the spark length has to be kept very minute.
(3) The cooling surface must be large and efficient (an ordinary desk fan was used to cool the experimental gaps).

For large-sized gaps such as would be required for the high power stations at Horsea, &c., water cooling would probably be necessary.

In connection with (1) each gap is made airtight and placed in communication with a small chamber provided with an oil seal, so as to maintain a constant pressure in the gap in spite of the rise and fall of temperature due to working.

The oxygen in the air originally filling the enclosed space is rapidly absorbed by preliminary working, leaving practically pure nitrogen.

In connection with (2) the spark plates must not be too light, as there is a great tendency to warp, due to the unequal heating of the inner and outer surfaces of the plates. It appears desirable for the sparking surfaces to be of annular form, as this affords better cooling of the actual sparking surfaces, and thus reduces the tendency to warp, also this construction offers fewer mechanical difficulties.

The present form of gap consists of a gun-metal casting to which is brazed an annular copper surface, which stands up some $\frac{1}{8}$ inch above a shoulder formed on the gun-metal base. Radiating fins are formed on the casting. Two of these castings are placed face to face, the distance between the copper surfaces being adjusted to about $\frac{1}{100}$ part of an inch. This distance is regulated by a woodite washer and several mica rings, the latter being of smaller internal diameter than the woodite.

When the gap is being adjusted. five insulated bolts, placed at equal intervals round the plates, are screwed down, compressing the woodite until the proper distance has been arrived at. The adjustment is then checked by means of a bridge megger, and any small alterations which may be necessary are effected. As a precaution against air leaks, the surfaces of the woodite washers and of the mica rings are covered with an insulating varnish, which is still wet when the rings are placed in position. Unreliability in the experimental sets was traced to the gaps not being air-tight (before varnish was adopted), or to the oil seal expansion chamber being too small, and oil getting sucked up into the gaps when they cooled down after working ; these and minor defects can be overcome by small changes in design, and as a result of the recent trials new gaps have been designed and a marked improvement and a really reliable working is looked for as soon as they are available.

Coupling.

It is essential that the coupling used with this type of installation should be tight, the coupling used in the "Vernon" is about 20 per cent. To obtain this coupling a special form of oscillator has to be used. A new design is being prepared in "Vernon" in which the coupling will be 25 per cent.

Range.

The range obtained with the "Vernon's" set approximates to that of the Mark II., the power taken being about 6 kw. The note, however, still remains bad and unreliable. Experiments will shortly be carried out in which the number of gaps is largely increased, the condenser value decreased and the power taken kept approximately the same.

The present arrangement for sending "W" tune is 720 jars and 4 gaps, each gap working at a pressure of about 700 to 1,000 volts R.M.S. With the arrangement about to be tried the condenser value is reduced to 40 jars and the number of gaps increased to 20.

Further minor alterations will be carried out, these consisting of improved oil-sealing arrangements, improvements in the method of connecting up the gaps, and of a modified form of oscillator, &c.

It is hoped that these modifications will result in an improvement in range and reliability, and especially in an improvement in the note.

The experiments described above, and all recent experiments, have been carried out with alternating current. Direct current is only suitable for small-power sets, since the use of high voltage direct current would lead to a large number of practical difficulties, and unless high voltage is available the number of gaps and consequently the power is limited.

Direct current has distinct advantages, however, as far as small-power sets are concerned, as a musical note can be obtained very simply, without the use of a high frequency alternator, in the manner described on page 42 of W.T. Appendix to Annual Report, 1908.

A direct current quenched spark set would probably be very suitable for short-distance sets.

General Remarks on the History and Theory of Quenched Spark System.

History.

The main principle of the quenched spark was discovered in 1906, but the development of this principle into a practical working set is very recent.

There are now three independent companies who make use of the principle. A number of patents that are owned by these companies have been published and the patent question is rather complicated. It appears that Baron von Lepel's master patent has the priority.

Professor M. Wien carried out a number of experiments with an ordinary coupled transmitting circuit, and measured on a wavemeter the waves that were produced. He found that when the primary and secondary were tightly coupled, two definite and very pronounced waves were given off, but that when he decreased the spark length in the primary and made it small, a third wave, half way between the other two, could also be detected with the wavemeter. The length of the primary spark gap was still further decreased, and the two waves originally observed decreased in strength and the third mean wave increased.

Eventually, when the spark length was made very small, of the order of one-tenth millimetre, the third intermediate wave was very strong and sharply defined, but no sign of the other two waves could be detected, showing that the transmitting circuit was generating a single wave only, and that this wave was powerful and but slightly damped.

Professor Wien showed this experiment in a lecture, an account of which was published in the "Physiklische Zeitschrift" of November 15th, 1906. Shortly afterwards the German Telefunken Company started experimenting, and they have since brought out wireless sets making use of the quenched spark principle under the name of "Singing Spark" sets. These sets have been fitted in several ships, most of them German, and appear to be very successful.

Quite independently of Professor Wien's results and of the Telefunken Company's experiments, Baron von Lepel produced his sets, which are described in Appendix to Annual Report, 1909. Although differing in detail, the main principle is the same as that discovered by Professor Wien.

A third type of the quenched spark system is that due to Dr. Peukert, who makes use of a very small gap between flat disc-shaped electrodes rotating under oil. Very little is known of this arrangement, and there appear to be no wireless stations making use of it for practical working. The system seems to be complicated and to have practical difficulties.

Theory of the Quenched Spark.

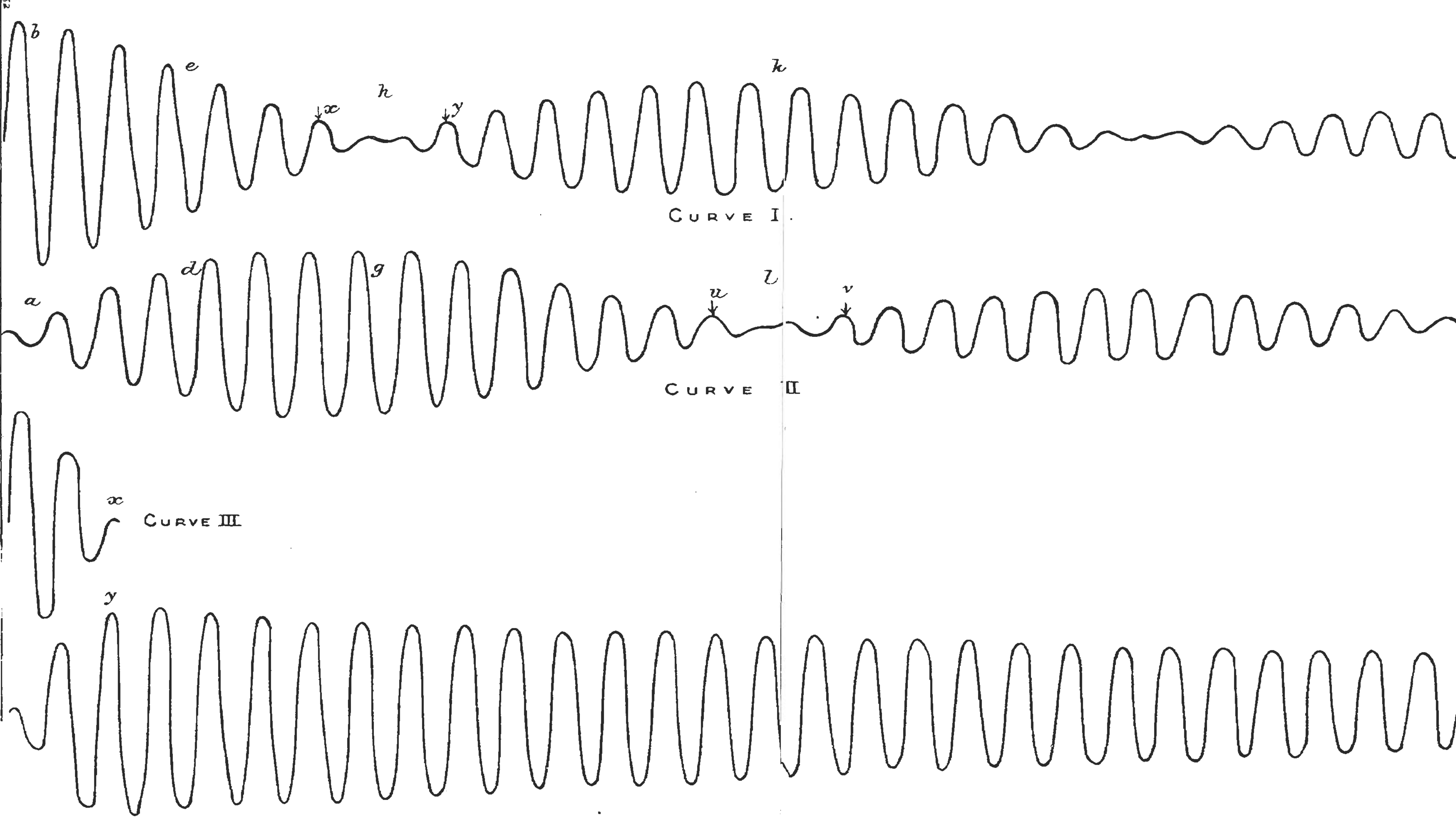
The method of working may be briefly explained by considering first what happens in an ordinary coupled spark set having a primary and secondary circuit in tune with one another. Curves I. and II. in Plate XI. represent the currents in such a circuit. These curves are plotted for a coupling of 6·67 per cent. Curve I. shows the primary current and Curve II. the secondary current.

The method of construction of these curves is shown in Plate XII., where the lower curves show the two waves that are present in the transmitting circuit. The lengths of these two waves are in the proportion of 29 to 31, which agrees with the definition of coupling—

$$\text{Coupling} = \frac{\text{Difference between wave lengths}}{\text{The mean of the wave lengths}},$$

$$i.e., \frac{31 - 29}{30} = \frac{2}{30} = 6 \cdot 67 \text{ per cent.}$$

These curves represent the current due to the two waves, and, in plotting them, the damping of both waves and the slightly greater amplitude of the current due to the shorter wave have been allowed for (the amplitudes of the currents due to the two waves are in the proportion of 29 to 31). Initially, the two waves are in phase with one another in the primary and 180° out of phase in the secondary; in the lower curves they have been plotted as starting in phase; to obtain the proportional value of the primary current, the ordinates taken from the lower curves must therefore be added; and to obtain the proportional value of the secondary current, the ordinates in the

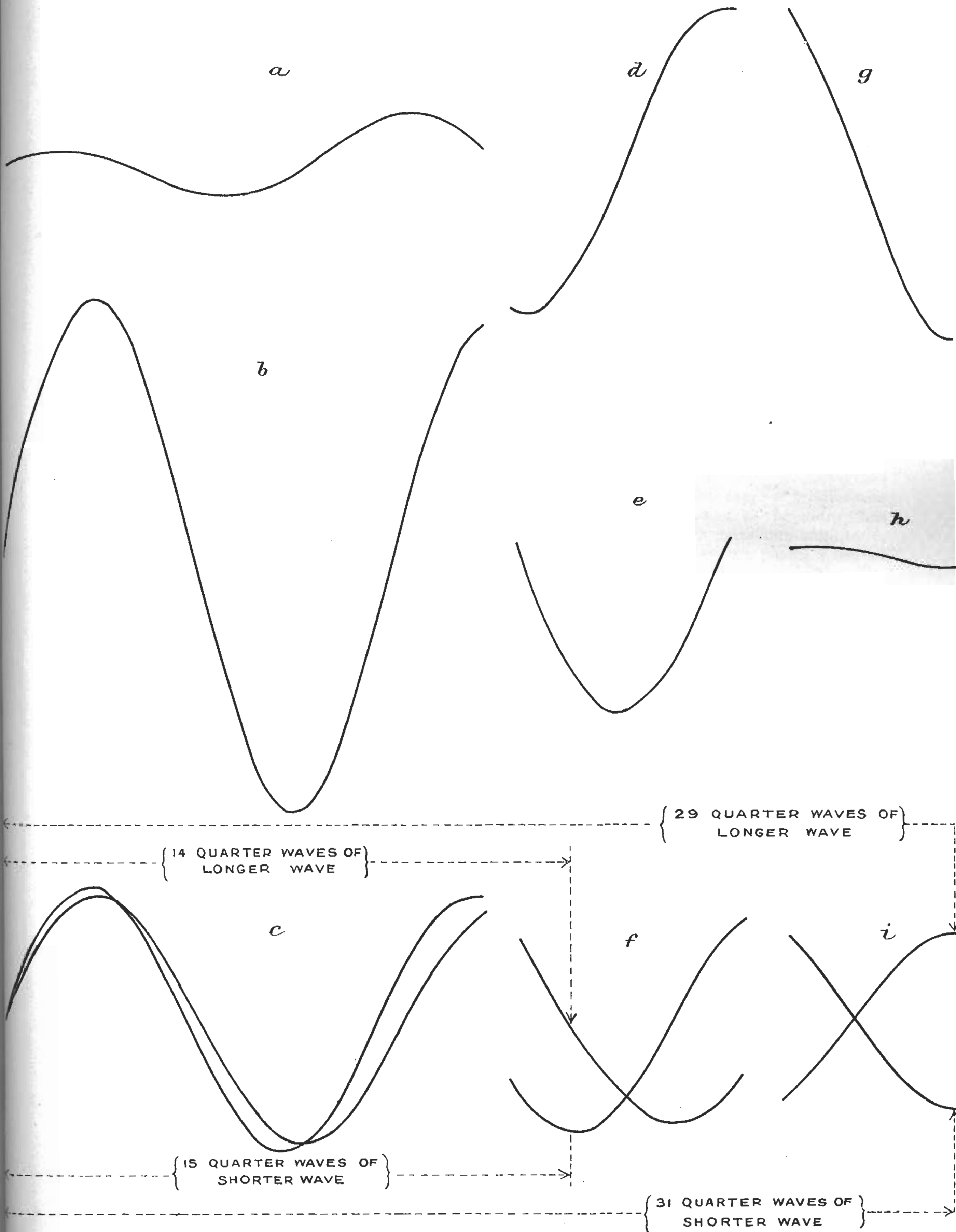


Curve I.

Curve II

Curve III

Curve IV


a
b
c
d
e
f
g
h
i
29 QUARTER WAVES OF LONGER WAVE
14 QUARTER WAVES OF LONGER WAVE
15 QUARTER WAVES OF SHORTER WAVE
31 QUARTER WAVES OF SHORTER WAVE

lower curves must be subtracted. The results of these additions and subtractions are given in the middle and upper set of curves, on the same scale as the lower curves. The letters a, b, d, e, g, and h, on Plate XI. and on Plate XII., indicate the same corresponding positions on the curves in the two plates. "a" and "b" are obtained from the two waves at "c," when they are practically in phase; the length of the resulting wave in the primary at "b" is practically equal to the mean of the lengths of the two waves at "c," and the resulting wave at "a" in the secondary has not yet sufficiently formed to have a definite wave-length.

At "f," the shorter, and therefore higher frequency, wave has advanced one-quarter wave length on the longer wave, and the two waves are 90° out of phase; the two resulting waves in the primary and secondary at "e" and "d" are now proportionally equal, and the total energy in the transmitter is equally divided between the primary and secondary. The wave-lengths of these resulting waves in the primary and secondary are now well defined and practically equal to the mean of the two component wave-lengths from which they result. At "i" the two component waves have got 180° out of phase, they are now opposing one another as far as the primary is concerned, and acting in conjunction as far as the secondary is concerned. The result is that the primary current has practically vanished, as at "h," and the whole energy has passed into the secondary. (The photographs obtained at Cleethorpes, showing the variations in the brightness of the spark, give an excellent practical illustration of the nature of the resulting current in the primary of a plain coupled transmitting circuit (*see* Plate XIV.).)

Considering the resulting Waves I. and II., it will be seen from Curve I. that the primary current gradually dies away, until at "h" it is practically zero, it then increases again, reaching a maximum at "k" (smaller than initially at "b" because of damping), afterwards dying away and increasing by turn. It will be noted that as the current passes through the vanishing point "h" it changes in phase, the distance between "x" and "y" being equal to two and a half wave-lengths (wave-lengths of the mean resulting wave measured where it is well defined at other parts of the curve).

Similar characteristics will be seen in Curve II., the distance between "u" and "v" being the length of two and a half waves. Comparing the two curves it will be seen that there is a difference of phase of 90°, or a quarter of a wave-length, between them, also that as soon as the energy has passed from the primary into the secondary, and the latter is oscillating with maximum amplitude, the energy commences to return to the primary; further, that when the energy passes a second time to the secondary that the resulting wave in the secondary has changed phase by 180°. The radiation from the secondary, and, therefore, the oscillations picked up by a simple (plain aerial) receiving circuit, accurately tuned to the mean wave-length in the secondary, will be affected by this change of phase in the secondary current. The oscillations that would be picked up from the radiation during the first period of activity of the secondary will be 180° out of phase with those that would be picked up during the second period of activity of the secondary. The result of this effect will be that the oscillations started during the first period of activity of the secondary will be damped down during the second period of activity of the secondary. Therefore when the receiving circuit is adapted for the receipt of one wave only, the efficiency of the radiation from this coupled transmitting circuit is limited by this change of phase.

When the receiving circuit, however, consists of a coupled circuit adapted for the receipt of two waves, and when it is adjusted to make these two waves equal to the two waves of which the transmitting oscillations are compounded, it is to be anticipated that greater efficiency may be expected; but as the secondary oscillations, and consequently the radiation from the secondary, varies in intensity as shown in Curve II., the arrangement would not be as efficient as if the oscillation, and therefore radiation, was at the full available intensity for the whole time. A practical difficulty that would be experienced with the receiving circuit thus adjusted to the two waves given out by a practical transmitting circuit, would be that the coupling would be too tight for selectivity. It would seem possible to design a receiving circuit to be suitable for the reception of the two transmitted waves and at the same time to be selective; such a circuit would probably have to have three adjustable couplings, but this possibility requires further investigation. Until such a circuit is produced, the selectivity of a receiving circuit receiving from a coupled transmitting circuit will be limited by the fact that it is only possible to allow a limited amount of the transmitted radiation to accumulate in the receiving circuit before the radiation changes phase; and a very selective receiving circuit, requiring the steady accumulation of a long train of radiation to work it, cannot be made use of. Pressure of work in "Vernon" has made it impossible to continue the investigation of these problems sufficiently far to specify the apparatus and outline the experiments that would be necessary to give the circuit proposed in this paragraph a proper practical trial. Even were this circuit produced, the fact that the radiation is transmitted and received in a series of beats must make the whole arrangement far less efficient than the quenched spark arrangement, described below, with its steady persistent radiation. Another reason for the comparative inefficiency of this coupled transmitting circuit is the fact that, in addition to the energy made use of in radiation and expended by the losses, due to brushing and resistance occurring in the secondary, a large percentage of the total energy is wasted in the primary, in resistance in condenser losses, and in the loss occurring at the spark gap. The spark gap loss is probably a very serious one, especially with sets such as the Mark II. sets, where it is undoubtedly increased by arcing. The brushing loss is probably a very serious one in the Mark II. installation, especially when the set is working with anything like full power and when it is increased by brushing at the rigging insulators, &c.

Returning to Plate XI., Curves III. and IV. represent the current, in the primary and secondary respectively, of a set using a quenched spark. A 20 per cent. coupling has been assumed. During the first two and a half waves the whole energy passes from the primary to the secondary. (The two component waves from which this part of the curves is obtained are in the ratio of 9 to 11.

$$\frac{11-9}{10}=\frac{2}{10}=20 \text{ per cent.}$$

These two waves get 180° out of phase when there have been 9 quarter waves of the longer wave and 11 quarter waves of the shorter wave, that is, 10 quarter waves, or $2\frac{1}{2}$ complete waves of the mean wave.) At the end of these $2\frac{1}{2}$ waves the points "x" and "y" are reached on the curves. The spark in the primary very rapidly increases in resistance as the current in the primary decreases, until, when the primary current gets very small at "x," the spark is "quenched," it ceases altogether and the primary circuit is broken at the spark gap. Since the primary circuit is no longer a complete circuit, the current in the secondary cannot induce currents into it; the whole energy therefore remains in the secondary, which will go on oscillating steadily with its natural wave-length, and it will not be damped by the resistance and spark gap losses in the primary. The secondary oscillates with the two component waves for such a very short time compared with the time during which it oscillates with a single mean wave, that the effect of the component waves on a receiving circuit can be neglected. The long train of slightly damped oscillations of the mean wave-length result in steady radiation at full intensity until the whole energy given to the secondary has been expended; the receiving circuit used can therefore make use of a long train of very persistent oscillations and can absorb energy steadily the whole time these oscillations are in existence, there is no change of phase or other objectionable feature about the radiation.

The quenched spark system would thus appear to produce an ideal transmitting circuit radiating a single very slightly damped wave. The above consideration of the reasons for the superiority of this system to the ordinary coupled system would lead one to expect that the old plain aerial transmitting arrangement would have to a large extent the same reasons for superiority, but in the plain aerial system these advantages are counterbalanced by, first, the tendency of the initial shock occurring with plain aerial to interfere with other stations, and, secondly, the long thin spark (that is obtained when any appreciable power is put into the aerial), the effect of which is to very seriously damp the oscillations in the aerial, so that the long train of slightly damped oscillation given by the quenched system is not obtainable, and only a short train of rapidly damped oscillations results.

In addition to the advantages that are described above it is considered that the quenched system will, due to steady and persistent radiation, travel through space with less loss than the ordinary coupled system, and a very marked increase in the strength of signals at long ranges is anticipated and has been indicated by the preliminary experiments with the quenched system; this property, however, requires further investigation. Another peculiarity of the quenched system is that, although the oscillations in the secondary are maintained for comparatively long periods at each spark, the oscillations in the primary cease very rapidly and leave the primary condensers and spark gap ready to be charged up for the next spark; there is no loss due to the charging circuit being short-circuited for an appreciable period by an arc at the spark gap. This peculiarity will make it possible to obtain a very rapid spark frequency and a correspondingly high piercing note, which is now well known to have very important advantages in penetrating atmospherics.

The exact reason for the quenching effect in the quenched gap is not fully known; it is in all probability a cooling effect, however; the following explanation is advanced as a general indication of the action; the true action is very possibly much more complicated, and would require a consideration of the motion and velocity of the electrons.

The conducting path in the case of a spark consists of gas and metal vapour at a very high temperature; this path remains a good conductor, provided the high temperature is maintained; but its resistance increases rapidly when the temperature falls. In an ordinary spark gap, the heating is produced by the current flowing across the gap and by the burning of the metal of which the sparking surfaces are composed; the cooling is produced by the conduction and radiation of heat to the electrodes; the gap is comparatively long and the electrodes comparatively small, the temperature of the conducting path is not therefore rapidly reduced. In the quenched gap the length of the spark is only 0·01 inch, and the sparking surfaces are large therefore, the cooling is very rapid; also there is no oxygen present, and there can, therefore, be no extra heating due to the burning of the metal; the temperature of the conducting path is, therefore, very rapidly reduced, and the path very rapidly increases in resistance and becomes non-conducting by the time the primary current has become small and reached the point "x" on the Curve III. in Plate XI. It would seem impossible for the cooling to be rapid enough to have any effect in the very small time available ($2\frac{1}{2}$ waves would only occupy $\frac{1}{120000}$ second in the case of "S" tune); an examination of the photographs in Plate XIV. will show, however, that there is a very marked change with an ordinary spark in an even shorter time than this.

The exclusion of oxygen is beneficial not only in preventing the formation of heat due to the burning of the copper, but also in preventing the formation of copper oxides, which are semi-conducting, and in preventing the burning away of the sparking surfaces and the formation of small pimples on them. A gap from which oxygen has been excluded presents a very bright, clean, copper surface, similar in appearance to copper newly deposited by electrolytic means. There seems to be little doubt that copper is thrown across from one sparking surface to another. If oxygen is allowed to enter a gap, and the sparking surfaces get irregular, they will not spark across regularly at the same potential difference for each spark; but they will allow sparks to occur at times other than when the charging potential reaches the peak of its sine curve, with the result that the sparking will be irregular and the note bad. A method of obtaining an absolutely uniform discharge in spite of slight irregularities of the sparking surfaces would be to adjust the gaps so that part of the gap is always equal to the critical distance at which the voltage to cause a spark is the minimum. This property of the voltage necessary to cause a spark, increasing when the spark length decreases beyond the critical distance, may open the way to further improvements. The critical distance, $\frac{1}{25000}$ of an inch, is so small, however, that it will probably be impossible to use it in a practical installation; as the pressure of the gas is decreased the critical distance increases, and it may be possible by using a partial vacuum in the gap to make practical use of the above phenomenon.

New Experiments.

Experiments with the quenched spark system are being made by "Vernon" with a view to introducing an entirely new set, in the first instance. This set would probably be of about the same power as the present Mark II. set; it will have a much higher note, however. Two experimental alternators, giving 800 cycles and 600 cycles respectively, are proposed, and, by obtaining a spark every half cycle, musical notes with frequencies of 1600 and 1200 will be obtained. After these experiments have been carried out, and if the new sets resulting from them are as successful as is anticipated, it may be thought advisable to modify the Mark II. sets in the more important modern ships to embody the quenched spark principle.

Experiments are also to be carried out at Horsea with the object of introducing quenched sparks at the high-power stations.