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P. C. HEWITT.

APPARATUS FOR PRODUCING OSCILLATORY CURRENTS.

APPLICATION FILED FEB. 9, 1903.

Fig.1

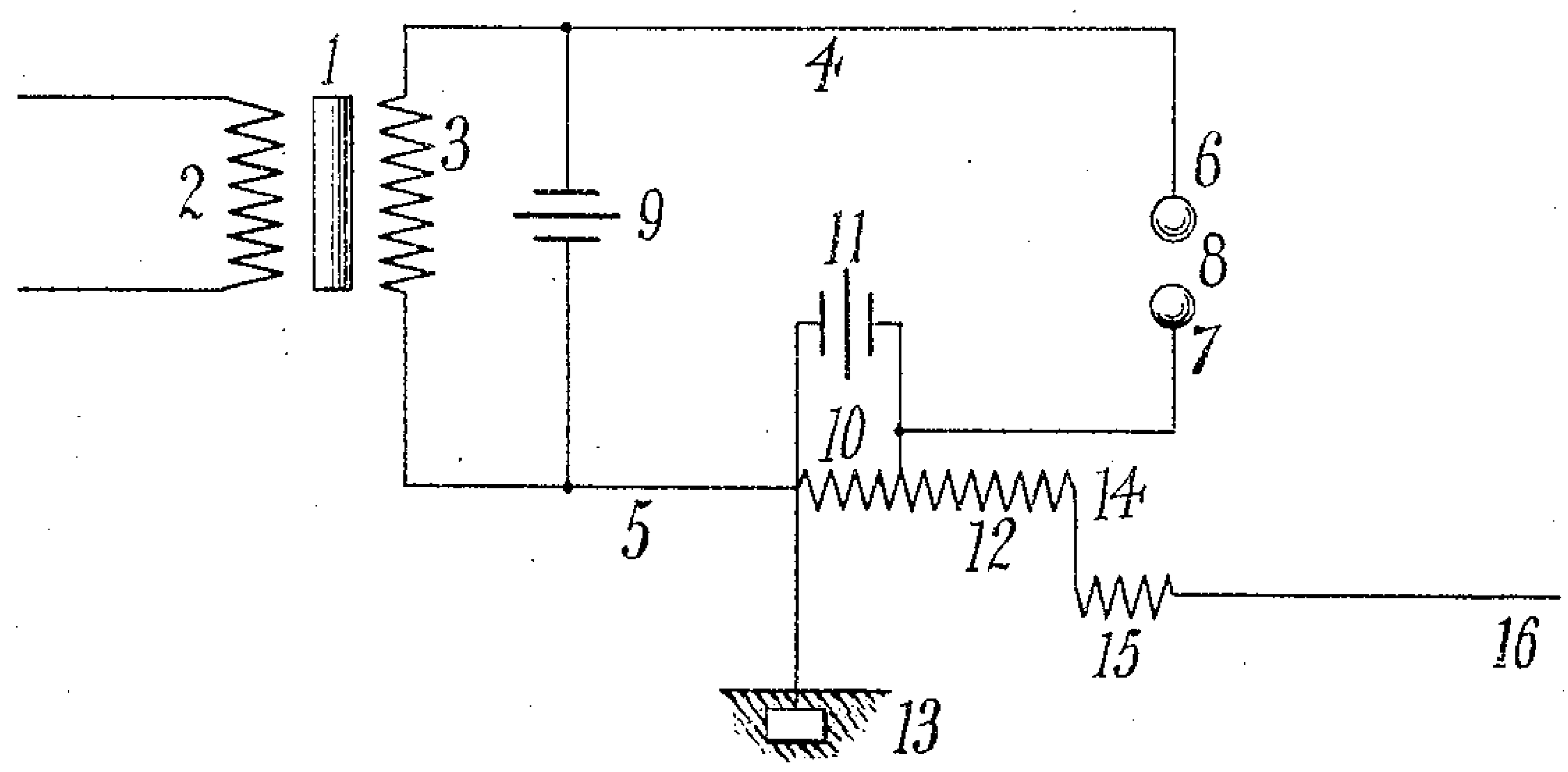


Fig.2

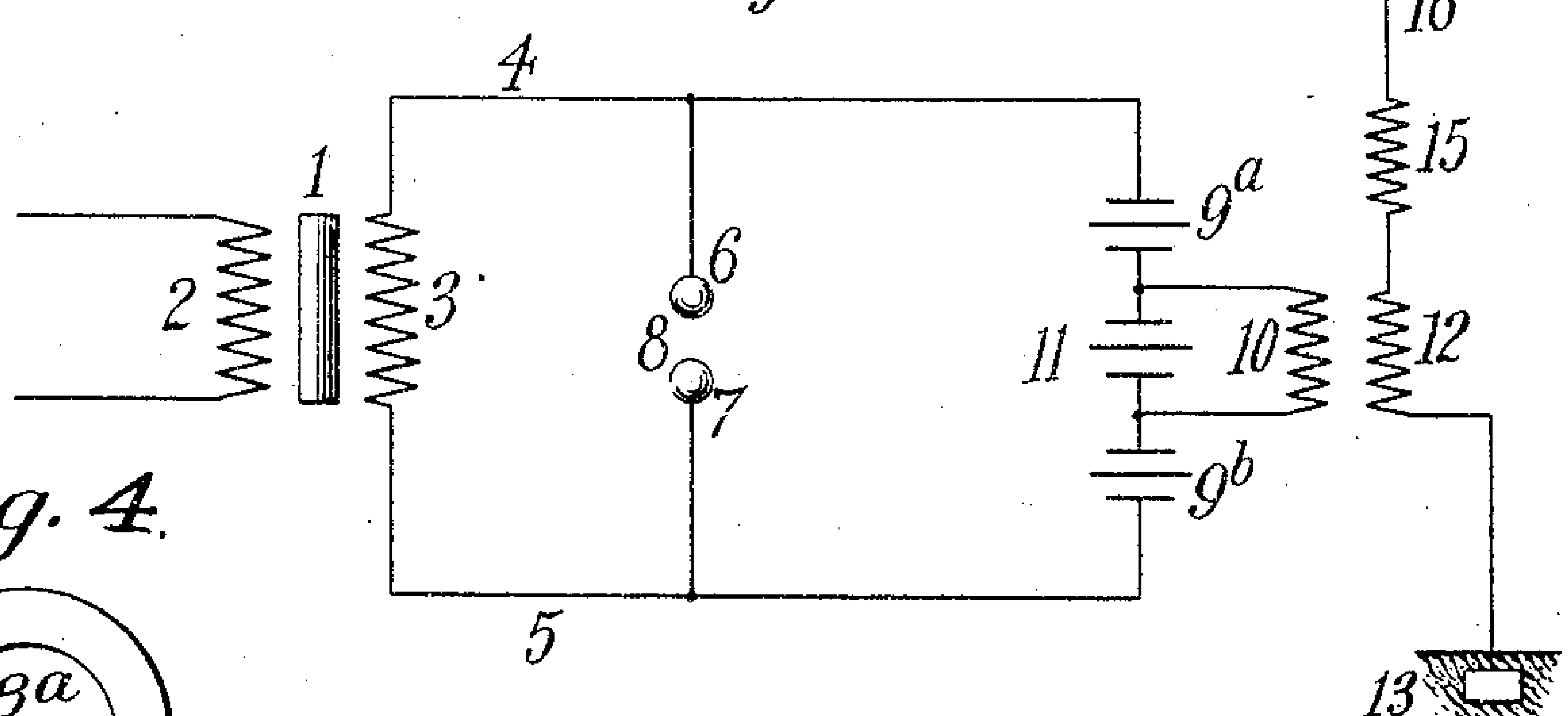


Fig. 4.

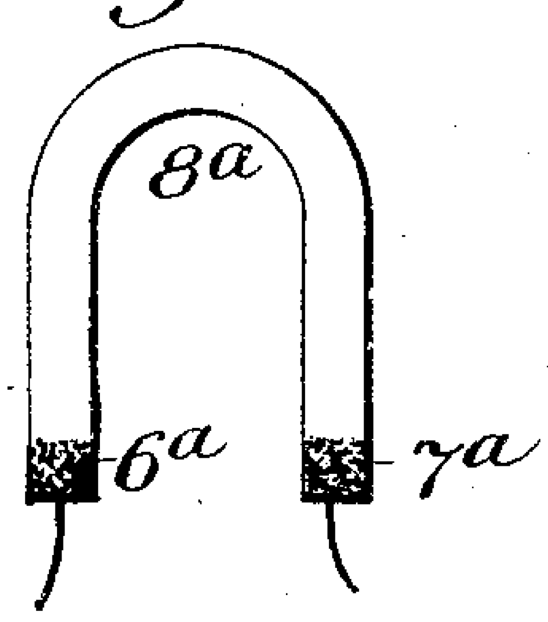
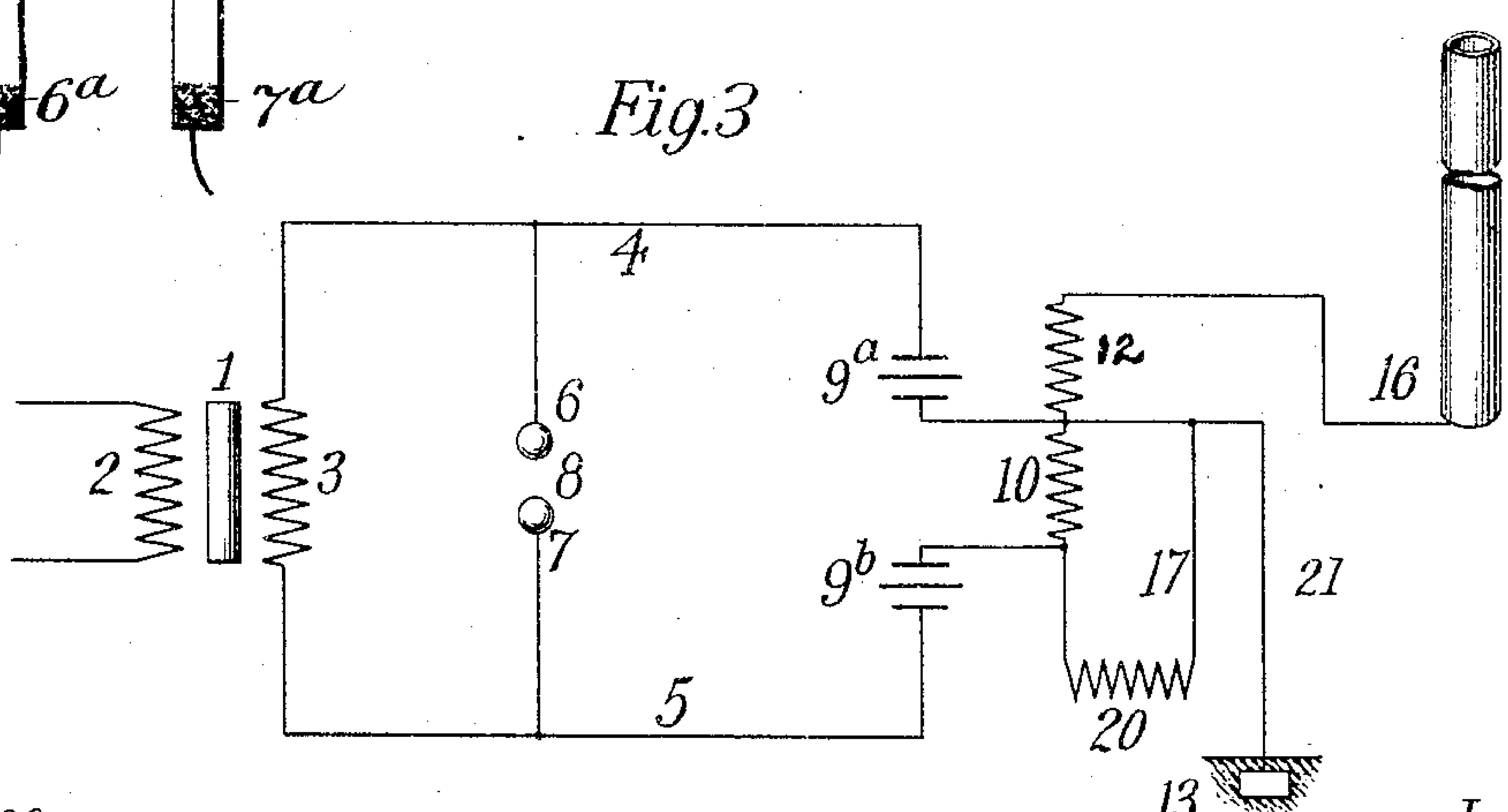


Fig.3



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UNITED STATES PATENT OFFICE.

PETER COOPER HEWITT, OF NEW YORK, N. Y., ASSIGNOR TO COOPER HEWITT ELECTRIC COMPANY, A CORPORATION OF NEW YORK.

APPARATUS FOR PRODUCING OSCILLATORY CURRENTS.

SPECIFICATION forming part of Letters Patent No. 780,997, dated January 31, 1905.

Application filed February 9, 1903. Serial No. 142,451.

To all whom it may concern:

Be it known that I, PETER COOPER HEWITT, a citizen of the United States, and a resident of New York, county of New York, State of New York, have invented certain new and useful Improvements in Apparatus for Producing Oscillatory Currents, of which the following is a specification.

My invention relates to means for producing oscillatory electric currents of the general character employed in wireless telegraphy and also the radiation of energy thereby.

The invention is useful not only for wireless telegraphy, but for other purposes.

The oscillatory electrical currents of the kind referred to are commonly produced by the discharge through an inductance of a charged condenser or capacity. The condenser discharge may be oscillatory if R^2 is less than 4L/C, R being the resistance, L the inductance, and C the capacity. Where R^2 is greater than 4L/C, no oscillations take place. In practice all losses, including those due to friction, induction, or radiation, may be included or reckoned as resistances. Where oscillatory, the oscillations are in the natural period of the system as determined by the inductance, capacity, and resistance thereof, and the persistence of the oscillations or wave-trains may be increased by minimizing the incidental frictional or other losses. Losses by radiation are of course inevitable, since in wireless telegraphy particularly radiation represents the useful work to be performed. The internal frictional losses are detrimental and serve no useful purpose. Of these internal detrimental losses that which occurs at the spark-gap is of considerable importance. As ordinarily constructed all of the energy stored in the condenser is forced to cross the spark-gap twice, first in one direction and then in the other, for each complete wave or oscillation; and the object of my invention is to provide an auxiliary oscillator designed, proportioned, and arranged in such relation to the prime oscillator that the said prime oscillator will transfer to said auxiliary oscillator all or, at least, a large fraction of the energy of the prime discharge. The function of the auxiliary oscillator is to elastically absorb said energy in such manner that it will oscillate persistently in its own natural period. The auxiliary oscillator has no spark-gap, and oscillations therein once initiated will persist much longer than is the case where all the energy must cross a spark-gap twice for each complete oscillation. It is obvious that where a unidirectional-discharge device or arrangement, like my vapor-lamp interrupter, is substituted for the spark-gap the advantages of an auxiliary oscillator such as described are very great, the auxiliary oscillator being excited or charged quite as efficiently by a single unidirectional discharge as it would be by several oscillations.

The invention can best be understood by reference to the accompanying drawings, in which—

Figure 1 is a diagram showing one organization of apparatus suited to carrying out the invention, and Figs. 2 and 3 illustrate modifications. Fig. 4 illustrates a special form of discharge device or spark-gap.

Referring to the drawings, 1 represents a transformer whose primary 2 is supplied with alternating currents of a suitable period—say sixty cycles. The secondary 3 is wound to have the required potential, which may be in the neighborhood of, say, ten thousand or twenty thousand volts. The terminals of the secondary coil 3 are connected to the conductors 4 and 5, which constitute a portion of the secondary circuit.

In Fig. 1 the circuit 3, 4, 5 is completed through the inductance 10 and condenser 11, which are in series with the transformer-winding and in parallel with each other. This is a well-known form of resonant-circuit, sometimes called an "antiresonant" circuit, because of its peculiar properties. It is not necessary to enter into elaborate technical description of the internal reactions of such a circuit in order to understand my present invention. It is sufficient to say that the inductance branch 10 and the condenser branch 11 together form a circuit resonant to one critical frequency and that when the current impressed thereon through the conductors 4, 5 is of that particular frequency the opposite reactancies of 10 and 11 balance each other in such manner as to produce a relatively great current-flow in the circuit 10, 11. Under these conditions the current in 4, 5 is at a minimum. The whole circuit 4, 5, 10, 11 is called "antiresonant" because the conditions in 4, 5 are quite the opposite to what they would be if the inductance 10 and condenser 11 were in series with each other as well as in series with 4, 5 instead of being, as they are, in parallel with each other and in series with 4, 5. In such an antiresonant circuit the branches 10, 11 together offer a great impedance to the passage therethrough of impressed currents of the one critical frequency to which they are resonant, whereas they offer much less impedance to impressed currents of all other frequencies.

By way of illustration, suppose the inductance 10 and condenser 11 of Fig. 1 adjusted so as to be resonant to a frequency of sixty cycles and the spark-gap closed. Then if the generator be run at such a speed as to give a frequency of twenty-five cycles practically all of the current may be made to flow through the inductance 10, restrained only by a relatively small impedance of said inductance, and very little of it will flow through the condenser 11, which offers a comparatively great impedance to currents of such low frequency. On the other hand, if the generator be rotated at a speed very much higher—say one hundred and twenty-five cycles—the inductance 10 will offer a relatively great impedance to such high frequency, whereas for said frequency the condenser 11 will offer a relatively low impedance, and most of the current will therefore flow through the condenser branch. If, however, the generator be rotated at a speed which will give a frequency of exactly sixty cycles, (the frequency to which the circuit 10, 11 is adjusted for resonance,) then approximately equal energies may pass in 10 and 11. The resonant rise of current therein will be great, and comparatively little current will flow in 4, 5. This opposition of 10 and 11 to the passage of currents of a particular critical frequency, and the resonant rise of current of such frequency in said branches 10 and 11 are utilized in a very efficient manner in the systems shown in Figs. 1 and 2, which figures will be recognized as embodying an oscillating circuit 4, 5 with the usual condenser 9 and spark-gap 8. The branches 10 and 11 are not made resonant to the sixty-cycle frequency of the generator, but to the natural oscillatory period or frequency of the circuit 9, 4, 6, 7, 10, 5. This is accomplished by making the condenser 11 approximately the same capacity as the condenser 9 and then adjusting the same until the maximum resonance effect is obtained.

With such system if wireless telegraphy is the intended purpose the natural period of discharge of the circuit may be, for example, one million per second, in which case the frequency to which the branches 10, 11 are resonant and to which they offer great impedance and in respone to which they develop great resonant rise of current is the same frequency—namely, one million per second.

The operation of this system of circuits involving my invention may be described somewhat as follows: The alternating current induced in the secondary 3 being of a frequency of sixty cycles, the time period of a half cycle or pulsation in one direction is one one-hundred-and-twentieth of a second. It is evident, therefore, that the rate of charge of the condenser 9 from the secondary 3 is enormously slower than the rate of discharge of said condenser through the circuit 4, 8, 10, 11, 5. It is so slow, in fact, that the potential rises uniformly through the circuit on each side of the spark-gap 8 and on the plates of the condenser 9 without the accumulation of any appreciable drop across the condenser 11 or across the coil 10. This slow rise of voltage continues until the spark-gap or equivalent breaks down, permitting abrupt discharge of the condenser 9. As has been explained, the system is so constructed that the natural or free discharge period of the condenser 9 across the spark-gap 8 is substantially the same as the period to which the circuit 10, 11 is resonant. The equilibrium of the circuit 10, 11 being thus abruptly disturbed in accordance with its own time period absorbs substantially all of the energy of the discharge of the condenser 9. The oscillatory disturbance being thus initiated, the inductance 10 and the capacity 11 continue discharging the one into the other until the energy is dissipated in radiation, frictional, or similar losses. This probable operation of the system may be made evident by considering that any circuit containing a condenser and a coil is set in oscillation when its electrical equilibrium is disturbed either by sudden charge or sudden discharge, the disturbed equilibrium being restored by oscillatory reactions between the condenser and the coil, which continue until the energy of the disturbance has been absorbed or dissipated. The circuit 10, 11 is itself a closed circuit containing a condenser and a coil capable of such equilibrium disturbance by sudden charge or discharge, and when thus disturbed equilibrium is again restored.

From the above it will be evident that after the first violent discharge of the condenser 9 practically all of the energy is absorbed in the circuit 10, 11 and oscillates therein after the manner described and that thus the invention secures persistent oscillations which are not subject to the great losses incident to forcing a discharge-path for the energy across a spark-gap twice for each complete oscillation or double vibration. The spark-gap loss is practically limited to a single discharge in one direction following each charge of the condenser 9. These prime discharges of the condenser 9 across the spark-gap 8 may be made to succeed each other with the greatest possible rapidity. Indeed, it would be desirable if they could be made to follow each other so closely as to supply fresh energy to oscillatory circuit 10, 11 before the oscillations caused therein by the preceding spark had been damped out.

The persistently-oscillatory circuit 10, 11 may be utilized as a source of high-frequency oscillatory energy in any desired way. For purposes of wireless telegraphy, for which it is more particularly designed, the ground connection is led from one terminal of the coil 10 and the aerial from the other terminal of said coil. As shown, additional coils or windings 12 are provided in inductive relation with the windings of the coil 10, the two coils together constituting what is known as an "autotransformer" or "autoconverter." An additional coil 15 may be added either as a part of the winding 12 or as a separate coil, and this may be utilized for adjusting the emitting-wire 13, 10, 12, 15, 16, so that its natural period of oscillation will be the same as that of the circuit 9, 4, 8, 10, 5. This condition may be approximated by making the entire length of the wire and windings 13, 10, 12, 15, 16 of a physical length slightly less than one quarter of the length in either of a wave having a time period equal to the time period of the oscillations in 9, 4, 8, 10, 5 or it may be an odd multiple of such quarter wave length. Synchronism of the circuits may then be perfected by adjusting the inductance of 15 until the maximum effect is observed.

It will be seen that the broad principle of the above arrangement involves elastic absorption of the condenser discharge in an auxiliary part of the system, thereby decreasing the potential available at the terminals of the spark-gap or equivalent discharge device to such an extent that after the first spark the potential at that point will not again reach the critical value necessary to disrupt the dielectric. As has been explained, even as arranged in Fig. 1 there will be some tendency to activity of the circuit 9, 4, 6, 5 even after the first spark; but this may be still further decreased by making the connected open circuit 13, 10, 12, 15, 16 a good oscillator, which of course means a circuit of low resistance and capable of holding in the form of electrification or magnetization a considerable amount of energy. Of course all energy passing into this circuit 13, 12, 15, 16 whether radiated from 16 or retained in an oscillatory state represents the load on the primary circuit 10, 11 and decreases the electromotive force available to sustain unnecessary activity of the condenser-circuit 9, 4, 8, 5. The amount of energy that can be held in 13, 12, 15, 16 may be greatly increased by making the electrical length of said circuit an odd multiple (as, say, three-fourths) of the wave length, though for wireless-telegraph purposes it is usually preferable to make this length one-fourth rather than three-fourths.

When the emitting-circuit is made three-fourths of a wave length, the coils 10, 12, and 15 may be so proportioned that together their capacity and inductance would give a time period to the oscillation equal to one-quarter of a wave length, 10, 12, being in inductive relation, then they will form a true resonant circuit and oscillate freely. The ground connection 13, 10 will be made equal to a second one-fourth wave length and the emitter 16 equal to a third one-fourth wave length, making three-fourths altogether, though an equivalent arrangement would be to make 15, 16 together a quarter of a wave length.

Another way of making the emitting-circuit a persistent oscillator capable of elastically absorbing and holding in the form of electrification or magnetization a sufficient amount of energy to render the discharge of the prime condenser 9 or its equivalent 9^a 9^b incapable of continued oscillation across the spark-gap is shown in Fig. 3, wherein a second inductance 20 is employed in the parallel to 10. This inductance 20 if of substantially the same resistance as 10 and if arranged in non-inductive relation with respect to 10 may be so proportioned as to capacity and inductance as to elastically absorb an amount of energy substantially equal to that taken by 10. By properly adjusting the lengths of 20, 17, 21 the oscillation thereof may be made to correspond and synchronize with those of the rest of the system, particularly if 10 and 20 are so wound as to have considerable mutual capacity between the turns. The precise adjustment is best found by trial. With such parallel inductance-coils used in connection with a very large capacity radiator, such as shown at 16, the emitting system 13, 21, 17, 20, 10, 12, 16 may be made to absorb a sufficiently large fraction of the energy of the discharge of the prime condensers 9^a 9^b as to render the spark-discharge non-oscillatory. This arrangement, like the others, is particularly useful in connection with the unidirectional vapor-lamp discharge device, and also with the spark-gap it is useful, for even if the proportions are not such as to prevent some oscillations across the spark-gap they will, nevertheless, store up a considerable fraction of the energy, and thus decrease spark-gap losses even though not preventing them altogether.

The action of inductance 20 may be accounted for in several ways. By being in parallel with inductance 10 it enables the adjustment of the inductance of the circuit without touching other parts of the apparatus—by making the inductance 10 equivalent to a smaller inductance, inasmuch as the two are in parallel. Further, the loss from 20 will be very slight and will again react on the circuit, as its energy is not absorbed by the circuit at the same time as the inductance 10, inasmuch as 20 is out of inductive relation with the remaining portions of the circuit, although it may aid in maintaining suitable phase relations.

It will be noted that one skilled in the art will be able to practically employ the inductance 20 whatever may be its theory of action, because the proper proportion thereof can best be determined by adjusting the same until the maximum effect is observed.

In Fig. 2 a modified arrangement is shown wherein the spark-gap 8 is located in a position corresponding to that of the condenser 9 in Fig. 1, and the condenser 9^a is located in a position corresponding to that occupied by the spark-gap in said Fig. 1. A second condenser 9^b is placed symmetrically with the condenser 9^a. The location and function of the inductance 10 and condenser 11 is the same as in Fig. 1, and as in said figure they form a closed circuit having the same natural period as the circuit 9^a, 10, 9^b, 7, 8, 6. In Fig. 2 the secondary winding in inductive relation to the primary 10 is made separate from the latter, after the manner of the more usual or conventional form of transformer construction, although the arrangement employed in Fig. 1 may be employed, if desired. In this system the emitting-circuit 13, 12, 13, 16 is adjusted to synchronism with the oscillatory circuit 10, 11, as in the arrangement of Fig. 1.

As there is difficulty in practice in adjusting the primary circuit to be exactly in tune with the secondary circuit, I usually prefer to so adjust the circuits that the primary oscillations shall tend to be shorter rather than longer than those of the secondary circuit. Where the secondary circuit is freely oscillatory, it tends to hold and bring the primary circuit into its own period. The tendency will then be for the secondary circuit to maintain its own period and to cause the primary circuit to adjust itself to that period, causing it to deliver its energy at the proper times. By having the secondary circuit oscillatory and approximately in tune with the period of the primary circuit I am enabled to accumulate an enormous amount of oscillating electrical energy in the secondary or discharge circuit when the secondary circuit is of such capacity and inductance as to give the maximum resonant rise at its terminal, and therefore to secure a corresponding radiation of energy from the emitting-circuit.

It will be understood that various forms of spark-gaps or discharge devices 8 may be employed. In practice I have found that a device of the general character of the gas or vapor electric apparatus described in certain patents issued to me on the 17th day of September, 1901, when adapted to this purpose may well serve the purpose.

In Fig. 4 I have indicated a discharge device 8^a comprising an electrode 6^a, which may be of any suitable material—such, for instance, as mercury—and an electrode 7^a, here represented as being of mercury, both inclosed in a suitable air-tight vessel previously exhausted and containing a rarefied atmosphere of mercury. I have found that such a device, while opposing a very high initial resistance, will permit a discharge under the influence of a high difference of potential, and the resistance between the electrodes 6^a and 7^a will almost instantly fall to a very low resistance upon the passage of a spark, thereby quickly draining the circuit, thus creating a very sharp and effective oscillation, and, further, the high initial resistance will reassert itself after the discharge of the condenser, thus necessitating its recharge.

I claim as my invention—

1. The combination of a circuit comprising a source of currents, a condenser or its equivalent and discharge device connected in shunt upon said source, an inductance in the discharge-circuit of the condenser, a condenser in shunt upon the inductance, and an emitting-circuit, a portion of which is in inductive relation to said inductance.

2. The combination with a source of currents, a discharge device connected with the respective terminals of such source, a condenser connected in parallel with the discharge device, an inductance traversed by currents from the condenser, a second condenser in shunt upon the inductance, adjusted to have with the inductance an oscillatory period approximately the same as the oscillatory period of the circuit of the first-named condenser.

3. The combination with the emitting or secondary circuit of a wireless-telegraph system having a given oscillatory period, of a primary circuit having a natural oscillatory period slightly less than that of the emitting-circuit.

4. The combination in a wireless-telegraph system, of an emitting-circuit having a given oscillatory period, of an exciting primary circuit, comprising a discharge device, a condenser in parallel therewith, and a subsidiary oscillatory circuit of approximately the same period as the primary oscillatory circuit whose connections are independent of the discharge device, whereby oscillations of that portion of the primary circuit affecting the secondary or emitting circuit may take place independently of oscillations through the discharge device.

5. The combination with the secondary or emitting circuit of a wireless-telegraph transmission system, of a primary or exciting circuit including means for establishing periodic discharges through the circuit, and a subsidiary oscillatory circuit of approximately the same period but free to oscillate independently of the means for establishing the periodic discharges.

6. In a wireless-telegraph system, the combination of the primary oscillatory circuit, of a vapor or gas discharge device consisting of an inclosing chamber, two electrodes and an intervening gas or vapor of a conducting substance, whereby sudden passages of current-flow are permitted.

7. The combination of a primary oscillatory circuit, a discharge device for creating oscillations therein, comprising a gas or vapor device of the character described, and a subsidiary oscillatory circuit of approximately the same period freely oscillatory independently of the discharge device.

8. In a wireless-telegraph system, the combination of a primary oscillatory circuit containing an inductance, a secondary or emitting circuit in inductive relation thereto, and an adjustable inductance in shunt upon the first-named inductance, as and for the purpose described.

9. The combination of a source of alternating electric currents, a capacity in shunt thereon, a discharge device consisting of a conducting gas or vapor device, having an initial high resistance, and a subsequent low resistance, in shunt upon the capacity, and a secondary circuit having inductive relation to the primary circuit.

10. The combination of a transformer, a capacity, an interrupter, an inductance in oscillatory relation, and a secondary circuit tuned to one-quarter of a wave length, or a multiple thereof, in such relation that the energy absorbed by the secondary will prevent the return impulse of the primary circuit from passing through the interrupter by reason of its transferred energy.

Signed at New York, in the county of New York and State of New York, this 4th day of February, A. D. 1903.

PETER COOPER HEWITT.

Witnesses:
WM. H. CAPEL,
PERCY H. THOMAS.