May 12, 1925. 1,537,671

C. W. HEWLETT

ENERGY CONVERTING ELECTRICAL INSTRUMENT

Filed Sept. 9, 1920 2 Sheets-Sheet 1

Fig. 1.

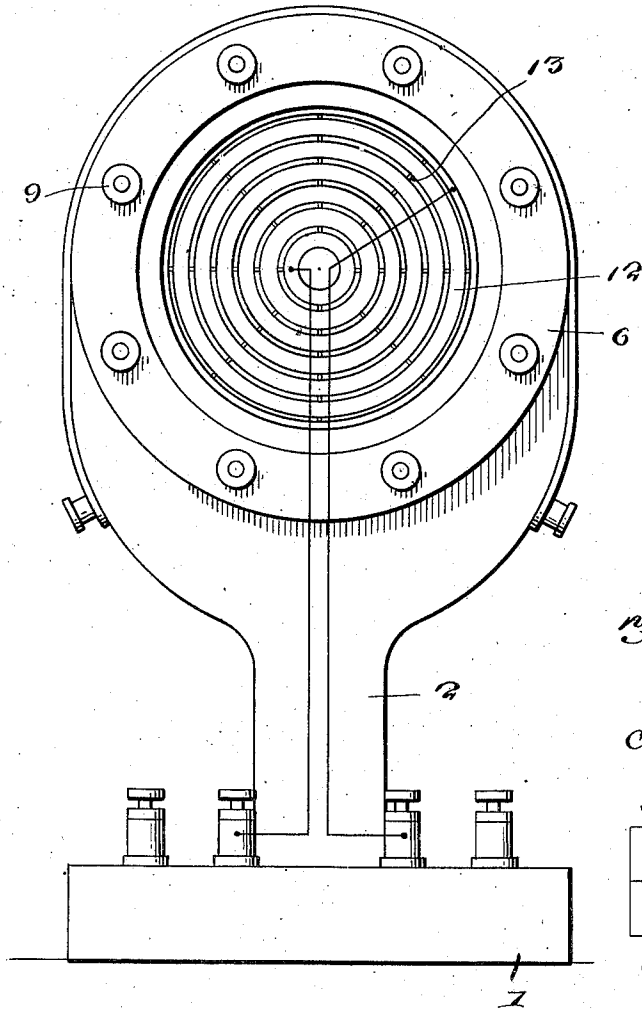


Fig. 2.

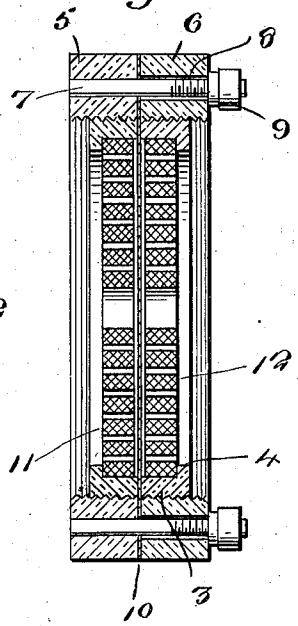
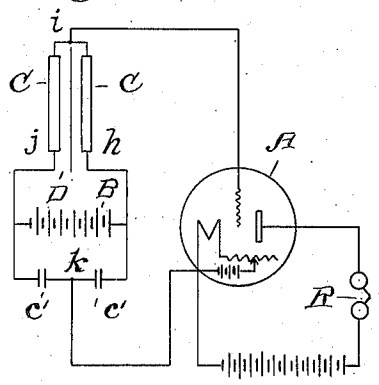


Fig. 2a



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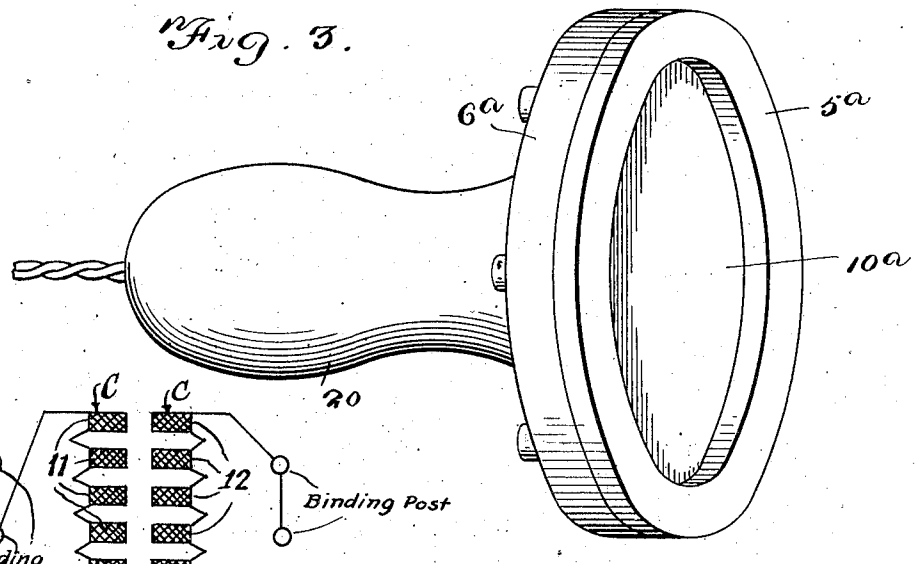
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Filed Sept. 9, 1920 2 Sheets-Sheet 2

Fig. 3.



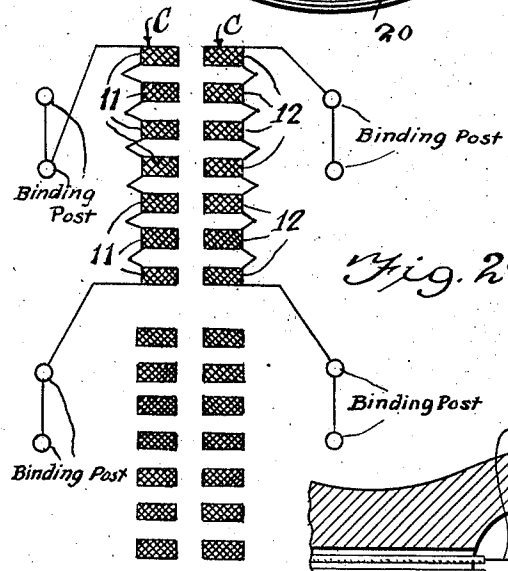
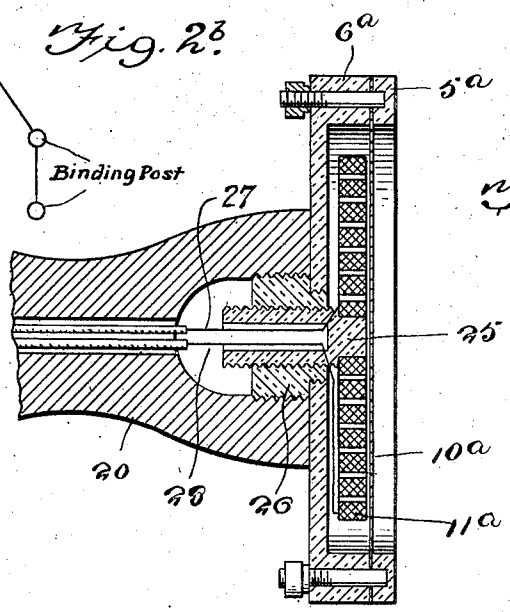


Fig. 2.

Fig. 4.



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UNITED STATES PATENT OFFICE.

CLARENCE WILSON HEWLETT, OF IOWA CITY, IOWA, ASSIGNOR, BY DIRECT AND MESNE ASSIGNMENTS, TO GENERAL ELECTRIC COMPANY.

ENERGY-CONVERTING ELECTRICAL INSTRUMENT.

Application filed September 9, 1920. Serial No. 409,212.

To all whom it may concern:

Be it known that I, CLARENCE W. HEWLETT, a citizen of the United States, residing at Iowa City, in the county of Johnson and State of Iowa, have invented new and useful Improvements in Energy-Converting Electrical Instruments, of which the following is a specification.

My present invention has for its object the provision of a practically advantageous instrument for converting the energy of variable electric currents into the energy of sound waves, and conversely for converting the energy of sound waves into energy of electrical currents.

To the attainment of the foregoing the invention consists in the improvement as hereinafter described and definitely claimed.

In the accompanying drawings, hereby made a part hereof:—

Figure 1 is a front elevation of one embodiment of my invention.

Figure 2 is a vertical diametrical section through the annular portion thereof.

Figure 2ª is a diagrammatic view hereinafter explicitly referred to.

Figure 2ᵇ is a diagram of the coil connections.

Figure 3 is a perspective of a modification.

Figure 4 is a detail diametrical section of a portion of the same.

Similar numerals of reference designate corresponding parts in Figures 1 and 2 to which reference will first be made.

In addition to supporting means including a base 1 and an upright 2, preferably of hard wood, the instrument shown in Figures 1 and 2 comprises fiber annuli 3, flanged at 4 and exteriorly threaded as shown; interiorly threaded holder annuli 5 and 6 of hard fiber, one of which is equipped with threaded rods 7 and the other with transverse bores 8 to receive said rods; nuts 9 on said rods; a diaphragm 10 preferably of aluminum and about .001 of an inch thick, interposed and clamped between the annuli 5 and 6; and pancake coil-members 11 and 12 fitting snugly in the rings 3. As shown each of the coil-members 11 and 12 comprises seven annular coils separated by air spaces, respectively wound with No. 22 B. and S. gauge copper wire, and having between 90 and 100 turns. The said annular coils are maintained in spaced relation by interposed sections 13 of wood or other appropriate material, and each annular coil is coated with shellac and bound at intervals with linen thread. The successive coils in each set are connected in series, as clearly shown in Figure 2ᵇ.

The instrument thus far specifically described is susceptible of use as a transmitter of sound. When so used, a direct current from a battery passes through the coils in series in such a way that the resulting magnetic fields in the two sets of coils oppose each other. In the region of the diaphragm the resultant of these two opposing magnetic fields is everywhere perpendicular to the axis of the coils. It is evident that the direction of this magnetic field lies along the radii of the diaphragm and hence may be briefly referred to as a "radial magnetic field." When sound waves strike the diaphragm it is made to vibrate to and fro. This to and fro motion of the diaphragm in the radial magnetic field generates variable circular electric currents in the diaphragm of the same character as the vibrations of the diaphragm. These variable currents in the diaphragm induce alternating electromotive forces in the two sets of coils, these induced electromotive forces being of the same character as the variable currents in the diaphragm. These induced electromotive forces may then be amplified and the amplified current received in an instrument of the same character as will be shown below or it may be received in any of the common forms of electromagnetic receiver.

Figure 2ª shows one method of using the instrument as described above.

In Figure 2ª:—

C C are the two sets of coils, D the diaphragm, B the battery for sending direct current through the two coils, and C′ C′ are two stopping condensers to afford a path for the induced electromotive forces in the two coils to be impressed on the amplifier A. R is a telephone receiver which responds to the amplified current. The direct current passes through one set of the coils from *h* to *i* and through the other set from *i* to *j*. It is to be noted that the induced alternating electromotive forces are in such directions that they oppose the direct current in one coil and aid it in the other. Hence, at a given instant, the alternating currents come out of the coils at *i* and come into the

coils at h and j. However, any unsteadiness in the direct current from the battery will not cause any induced electromotive force to be fed to the amplifier for such induced electromotive forces will be opposed to each other in the two sets of coils; and if the two sets of coils are alike and the diaphragm the same distance from each, these induced electromotive forces will neutralize each other and produce no effect. Manifestly, a transmitter characterized as stated is free from the many faults common to the carbon granule transmitter.

At this point I would have it distinctly understood that the adjustable arrangement hereinbefore described is in no wise essential, and that, as a matter of fact, a better construction would be one in which the annuli holding the coils are mounted a fixed distance apart, say one thirty second of an inch, with the diaphragm supported half way between them.

The instrument may also be used as a receiver for voice currents. Referring to Figure 2[a] it is clear that if such variable currents are sent into the instrument at i, coming out at h and j to k, these variable currents will induce circular currents in the diaphragm which will react with the radial magnetic field causing mechanical vibration of the diaphragm as is described more in detail in the description of the one coil member embodiment hereinafter described. For use as a head receiver it has been found preferable to separate the two coils and mount a separate diaphragm close to each coil. The two halves of the instrument may then be placed one half at each ear. For this purpose each coil of the instrument may be wound of about five thousand turns of No. 40 B. and S. gauge enamelled copper wire. This makes a coil about $\frac{1}{12}$ inch thick and $2\frac{1}{4}$ inches in diameter with a hole in the center $\frac{3}{8}$ inch in diameter. It is found that a thicker diaphragm, say $\frac{1}{32}$ inch thick, gives the best results as a transmitter of voice currents.

Again the instrument will serve as a precision source of sound at any desired frequency, and the intensity can easily be varied by varying the direct current. At frequencies of 14000 vibrations per second the sounds can be heard several hundred feet away. The waves from the instrument are nearly plane and such short wave lengths can be concentrated at a point by means of spherical reflectors.

It will be further understood that in the instrument described the direct current provides a polarizing field in the diaphragm, and the diaphragm vibrates with the same frequency as the alternating currents. Said polarizing field is radial in the diaphragm—i. e., perpendicular to the axis of the coils, and it is this polarizing radial field which reacts with the currents in the diaphragm caused by the alternating current. At this point it is well to state that in the one coil-member embodiment hereinafter described and in which one side of the diaphragm is entirely free it is the radial component of the field due to the direct current which is the effective polarizing field.

The instrument of Figures 3 and 4 comprises a handle 20, holder annuli 5[a] and 6[a] connected together and to the handle 20 as shown, a diaphragm 10[a] clamped between the annuli 5[a] and 6[a], and a coil-member 11[a], arranged at the inner side of the diaphragm 10[a], and connected with the holder annuli and the handle in the manner shown or in any other manner compatible with the purpose of my invention. This instrument of Figures 3 and 4 can be connected with a battery sufficient to give one-half to three-fourths of an ampere through the coil member 11[a]. The alternating or variable current will cause the diaphragm 10[a] to respond with mechanical vibrations of the same character as that of the impressed alternating current. A choke coil may be used to prevent the alternating current from passing through the battery while a large capacity may be used to prevent the direct current from passing through the source of alternating current. The operation of the instrument is as follows:—The direct current produces a magnetic field in the diaphragm 10[a]. This may be regarded as made up of two components—i. e., a component along the direction of the axis of the coil, and a component along the radii of the diaphragm. Now when the alternating current passes through the coil there is induced in the diaphragm circular currents whose common axis is the coil member 11[a]. These currents react with the radial magnetic field causing to and fro motion of the diaphragm which causes sound waves to be produced.

The instrument just described is possessed of the following advantages over the ordinary telephone receiver. (1) In case a non-magnetic diaphragm for instance aluminum, is used there is no hysteresis loss, and in any case a minimum hysteresis loss which makes this piece of apparatus particularly useful for high frequency work. (2) A minimum eddy current loss. These two advantages make the instrument especially useful for a telephone receiver, in that there is a minimum distortion of a complex alternating current. This distortion is due to a selective damping of components of different frequency. The force acting upon the diaphragm is also uniformly distributed over its area. These points of advantage assure an unusually faithful reproduction of voice currents.

An enlarged instrument such as just described can be used for addressing audiences

or where any loud speaking instrument is necessary.

In the form of my invention shown in Figs. 3 and 4, the coil member 11ª may be wound with No. 18 B. and S. gauge wire and contain about 300 turns; this member may be held in the center through the medium of a fiber plug 25, threaded into another fiber plug 26 which, in turn, is threaded into the handle or casing 20. The leads 27 and 28 of the coil member 11ª are passed through the plugs and handle or casing as shown.

It will be apparent from the foregoing that my improvement embodies no iron and hence is not subject to hysteresis loss which especially adapts it for carrying high frequency alternating currents; also, that the improvement embodies a minimum amount of conducting material and therefore is liable to lose but little energy in the form of hysteresis and eddy current losses which fits it especially for high frequency alternating currents; also, that the improvement is susceptible of use directly as part of or as the whole of the inductance in a tuned resonant circuit. If the improved instrument is used as part of the inductance in the tuned circuit, then the remainder of the inductance in the circuit may be part of an auto transformer, another tap being taken off at another point to feed back to the grid of the three-element vacuum tube. In the event of my instrument being used as the whole of the inductance in the tuned circuit then the feed back to the grid may be wound around the outside of the instrument. This using the instrument as the whole of or part of the inductance of the tuned circuit results in obtaining the maximum efficiency.

It is to be understood in conclusion that the diaphragm included in my appended claims may in some cases be magnetic although usually for high frequency work it would be desirable to use a non-magnetic diaphragm.

In Figure 4 the coil is shown as made up of annuli. I desire it distinctly understood however, that I prefer in the actual instrument to employ the coil in compact or solid pancake-coil form.

In the two coil device the coils are divided into annuli to enable sound to pass readily through the coils to the diaphragm when used as a transmitter, and from the diaphragm when used as a receiver or tone generator. By reason of this provision the sound does not have to pass through a restricted passage as would be the case if the coils were made solid and a more faithful reproduction of the original sound is thereby obtained.

A solid coil in the embodiment shown in Figure 4 is advantageous since by such coil a strong magnetic field can be secured.

Having described my invention, what I claim and desire to secure by Letters-Patent is:—

1. A telephone instrument comprising a fixed pancake coil and a diaphragm of non-magnetic conducting material adjacent thereto, said coil being adapted to carry a constant direct current and a variable current, and said diaphragm being adapted to vibrate solely by reason of the reaction between variable currents induced therein by the variable current in the coil and the magnetic field produced by the direct current in the coil.

2. A telephone instrument comprising a fixed pancake coil and a diaphragm of conducting material adjacent thereto, said coil being adapted to carry a constant direct current and a variable current, and said diaphragm being adapted to vibrate solely by reason of the reaction between variable currents induced therein by the variable current in the coil and the magnetic field produced by the direct current in the coil.

3. A telephone instrument comprising a fixed pancake coil and a diaphragm consisting of a sheet of non-magnetic conducting material adjacent and parallel thereto covering substantially the entire area of the coil.

4. A telephone instrument comprising a fixed pancake coil and a diaphragm of non-magnetic conducting material adjacent and parallel thereto covering substantially the entire area of the coil, said coil being adapted to carry a direct current which will produce a radial magnetic field in said diaphragm whereby the vibration of said diaphragm in response to sound waves impinging thereon will cause the generation in the diaphragm of variable currents corresponding to the sound waves and the variable currents thus generated will induce corresponding currents in the coil.

5. A telephone instrument comprising fixed windings and a diaphragm of conducting material adjacent thereto, said windings being adapted to carry a direct current whereby a radial magnetic field may be produced throughout substantially the entire area of the diaphragm, and to carry a variable current which will induce corresponding variable currents in said diaphragm and produce vibration of the diaphragm solely by reason of the reaction between the variable currents induced therein and the radial magnetic field about the diaphragm produced by the direct current.

6. A telephone instrument consisting of a pair of like pancake coils mounted upon opposite sides of an electrically conducting diaphragm, said coils being adapted to carry simultaneously a variable current and a direct current, the electrical connections of the coils being such that the effect of the

direct current is to produce a constant radial magnetic field in the diaphragm, while the variable currents produce a variable magnetic field perpendicular to the diaphragm.

7. A telephone instrument consisting of a pair of like pancake coils mounted upon opposite sides of an electrically conducting diaphragm, said coils being adapted to carry simultaneously a variable current and a direct current, the electrical connection of the coils being such that the direct current may be caused to flow through the two coils in series while the variable current may be caused to flow through the two coils in parallel whereby the magnetic fields produced by the direct currents in the two coils oppose each other and the magnetic fields produced by the variable current in the two coils assist each other and cause variable currents to be induced in the diaphragm.

8. A telephone instrument consisting of a pair of fixed pancake coils mounted upon opposite sides of a diaphragm formed of electrically conducting material, said coils being adapted to carry a direct current producing a constant radial magnetic field in the diaphragm, whereby mechanical vibration of the diaphragm by sound waves impinging thereagainst will result in the generation of variable currents in the diaphragm corresponding to the sound waves, which currents will induce corresponding currents in the pancake coils.

9. A telephone instrument consisting of a pair of fixed pancake coils mounted upon opposite sides of a diaphragm formed of electrically conducting non-magnetic material, said coils being adapted to carry a direct current producing a constant radial magnetic field in the diaphragm, whereby mechanical vibration of the diaphragm by sound waves impinging thereagainst will result in the generation of variable currents in the diaphragm corresponding to the sound waves, which currents will induce corresponding currents in the pancake coils.

10. A telephone instrument consisting of a diaphragm of electrical conducting non-magnetic material, and a pancake coil mounted adjacent to and parallel with said diaphragm and distributed over an area substantially equal to that of the diaphragm, said coil being adapted to carry a direct current, whereby impingement of sound waves on said diaphragm resulting in vibration thereof will generate variable currents in the coil.

11. A telephone instrument consisting of a supporting structure, a vibratory diaphragm of conducting material mounted within said support, and a pair of pancake coils mounted upon opposite sides in close parallel relation to the diaphragm, said coils being adapted to carry a direct current and a voice current, and formed of annular concentric sections spaced apart from one another.

12. In a telephone instrument, a supporting structure, a diaphragm of non-magnetic conducting material mounted therein, and pancake coils mounted at opposite sides thereof in close parallel relation thereto, each of said coils consisting of a series of annular concentric sections spaced apart from one another.

In testimony whereof, I affix my signature.

CLARENCE WILSON HEWLETT.