Oct. 20, 1931. C. R. HANNA 1,828,284

VIBRATORY SYSTEM

Filed Nov. 7, 1927

Fig. 1.

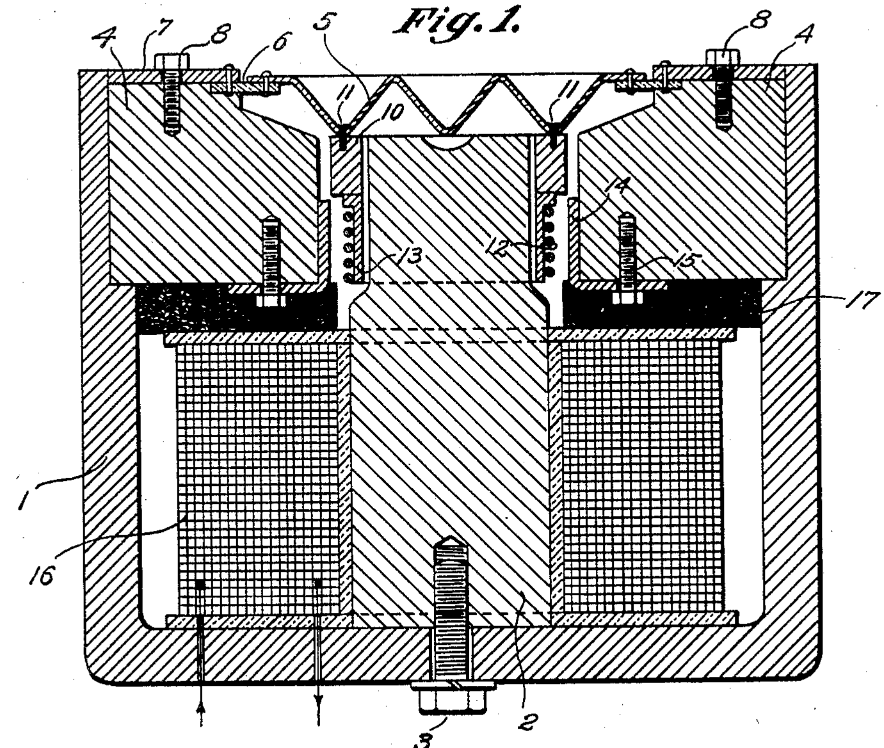


Fig. 2.

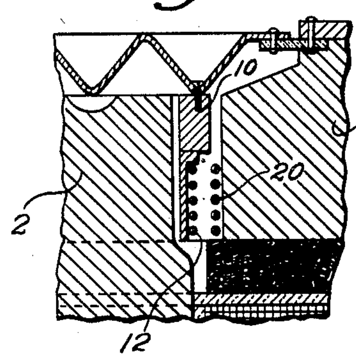


Fig. 3.

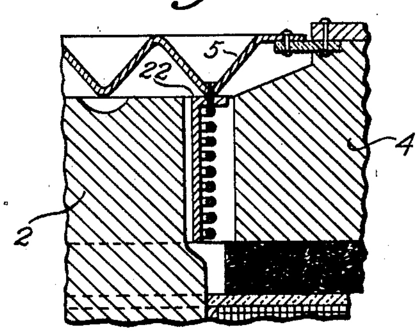


Fig. 4.

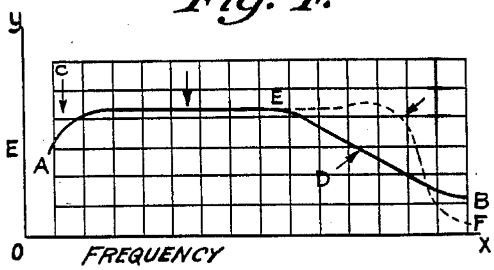
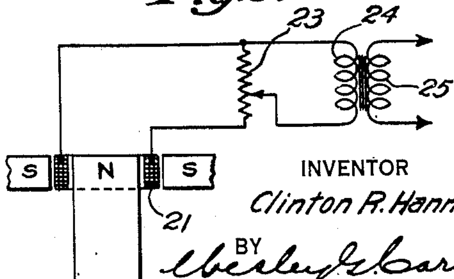


Fig. 5.



INVENTOR

Clinton R. Hanna

BY *Wesley G. Carr*

ATTORNEY

Patented Oct. 20, 1931 **1,828,284**

UNITED STATES PATENT OFFICE

CLINTON R. HANNA, OF EDGEWOOD, PENNSYLVANIA, ASSIGNOR TO WESTINGHOUSE ELECTRIC & MANUFACTURING COMPANY, A CORPORATION OF PENNSYLVANIA

VIBRATORY SYSTEM

Application filed November 7, 1927. Serial No. 231,509.

My invention relates to vibratory systems, and it has particular relation to systems of the type known as "microphones", wherein air-pressure fluctuations are translated into electrical-potential or current variations.

It is common knowledge among workers in the art that microphones of substantially all types tend to give a somewhat distorted output when subjected to sounds having a wide range of frequencies. Certain frequencies or frequency-bands are often over-emphasized by the resonance characteristics of the moving parts of the microphone and, for that reason, few microphones are capable of giving a substantially constant response over a wide frequency range.

It is accordingly an object of the present invention to provide a microphone or an analogous device with means whereby the velocity of the diaphragm or principal moving part thereof is independent of frequency and is faithfully proportional to the applied sound pressure.

Another object of my invention is to provide a microphone having incorporated in a movable portion thereof means for electromagnetically damping its motion.

Another object of my invention is to provide, in a device of the type designated, means whereby damping currents are prevented from causing distorted electrical pulsations not truly representative of impinging sounds.

I accomplish the above objects in one preferred embodiment of my invention by providing a microphone of the moving-coil type with a supplementary closed coil, also sound-actuated, in which eddy currents are generated by reason of its motion in a magnetic field. The reaction of the eddy currents with the magnetic field provides the necessary damping and, in order that these currents shall not influence the output from the microphone, shielding means are interposed in such relation to the closed coil that its influence on the coil generating the desired output voltages is minimized. The shielding means may either be a closed multi-turn coil, or it may comprise merely a single closed turn having low resistance and placed co-axially with the coils in which the damping-currents and the currents representative of sounds are generated by the motion thereof in the magnetic field.

In a further modification of my invention, a single winding, short-circuited through a resistor, constitutes both the eddy-current and sound-current generator, and only a small portion of the generated voltage which appears at the resistor is utilized to energize a thermionic amplifier.

Among the novel features of my invention are those particularly set forth in the appended claims. The invention itself, however, both as to its organization and its method of operation, together with further objects and advantages thereof, will best be understood from a consideration of the following description of certain specific embodiments, taken in connection with the accompanying drawings, in which:

Fig. 1 is a view, in cross-section, of a microphone comprising a preferred embodiment of my invention, the relative proportions thereof being greatly exaggerated.

Figs. 2 and 3 are fragmentary cross-sectional views of modified forms of my invention.

Fig. 4 is a diagram illustrating the improved response obtained from a microphone constructed and arranged according to a modified form of my invention.

Fig. 5 is a diagrammatic view illustrating the mode of construction and manner of operation of the modification of my invention shown in Fig. 3.

The device shown in Fig. 1 comprises a cup-shaped member 1 of magnetic material, in which a central pole piece 2 is axially positioned and is held firmly in place by a screw 3 or an analogous device. An annular pole-piece 4 is mounted in the open end of the member 1, the central opening thereof cooperating with the pole-piece 2 to define a circular air-gap.

A corrugated or otherwise stiffened diaphragm 5 is mounted on a flexible annulus 6 of rubber or analogous material, the periphery of the annulus being clamped to the circular pole-piece 4 by a ring 7 held in position by a plurality of screws 8. The exact manner in which the diaphragm 5 is resiliently suspended constitutes no part of the present invention, many other ways of mounting it being equally as effective as the way shown.

An aluminum ring 10 is attached to the under portion of the diaphragm by a plurality of screws 11, or by other appropriate means, and a coil 12 is affixed to a supporting tube 13 carried by the under edge of the aluminum ring. Although not so shown in the drawings, the support 13 for the coil may be a thin skirt made integral with the ring 10, in which event, the support is provided with a plurality of axial saw-cuts to prevent the circulation of eddy-currents therein.

Both the ring 10 and the coil 12 are positioned in the circular air-gap, for a purpose that will later be explained in detail.

A copper flange 14 of L-shape in cross section, is mounted on the lower face of the circular pole-piece and is held in place either by friction or by a plurality of screws 15, as illustrated.

The central pole-piece is surrounded by a magnetizing coil 16, through which direct current may be passed to give the desired flux-density in the air gap. In one commercial embodiment of my invention, the coil comprises 1900 turns of No. 18 wire, having a resistance of 8 ohms, and the magnetizing current was 1 ampere. This gave a flux-density of 12,000 gausses, which was entirely satisfactory.

A ring 17 of packing material, such as felt, wool, or the like, may advantageously be disposed between the energizing coil and the under portion of the annular pole-piece, to prevent resonance effects from the chamber in which the coil is mounted.

When the diaphragm 5 is exposed to sound-waves, it is set into vibratory motion, and voltages are induced in the ring 10 and the coil 12 which are proportional to the velocity of vibration. The coil 12 is preferably connected in series with the primary of a step-up transformer (not shown), the secondary of which is comprised in the input circuit of a thermionic device.

The voltages induced in the ring cause eddy-currents to flow therein, the magnitude of these currents being proportional to the velocity of vibration of the ring in the air-gap. The eddy-currents react with the magnetic field to oppose the motion of the ring therein, the amount of reaction being proportional to the current and, consequently, proportional to the velocity of vibration.

Unless otherwise prevented, the eddy-currents flowing in the ring 10 induce voltages in the coil 12 which are out of phase with the voltages induced therein by reason of its movement in the magnetic field, and give rise to a distorted output. The copper flange 14 has the very important function of electrically shielding the coil from the effects of the eddy-currents in the ring. The flange is directly in the path of the flux emanating from the ring, and prevents the energy from being transferred to the coil therefrom. Perhaps another way of stating the function of the copper flange would be to say that secondary eddy-currents are induced therein by the flux emanating from the ring, and that the magnetic field of the secondary eddy-currents, being substantially equal, and opposite in direction, to the field from the ring, neutralizes the effect of the ring eddy-currents on the coil. Irrespective of the exact manner in which the flange functions, however, it is an extremely important part of my invention, in that it prevents substantially all distortion caused by induction from the damping currents.

In an alternative form of my invention illustrated in Fig. 2, the copper flange 14 is replaced by a stationary coil 20 having substantially the same number of turns as the movable coil 12 carried by the diaphragm, the two coils being connected in series. Both coils are mutually coupled to the damper-ring 10, and the voltages induced therein by the eddy-currents flowing in the ring are substantially equal. By properly connecting the two coils together, these voltages may be caused to so cancel that the only voltage appearing at the terminals of the movable coil is that voltage caused by its motion in the magnetic field.

The damper-ring 10 does not necessarily have to be made from a single short-circuited turn; it may consist of a plurality of turns, if desirable, closed through a low-resistance element. If the total volume of wire is the same, the damping will be independent of wire size, thus permitting a fairly wide leeway in the choice of the wire to be used.

It is of some advantage, if a damper consisting of a plurality of turns of wire is used, to connect it in series with an inductor (not shown) arranged to offer increasing impedance at higher frequencies. By properly choosing the constants of the inductor, the phase and magnitude of the eddy currents may be so adjusted that, in the upper range of frequencies, a reaction is produced which is opposite to that of the mass of the vibrating system.

The effect of the inductor in series with the damper winding is illustrated in Fig. 4, which is a curve representing the relation between the voltage appearing at the terminals of the movable coil to the sound frequency, over a wide range of sound frequencies. The full line A—B represents the response of a vibratory system in which the damper ring is a single closed turn, or a plurality of turns closed through a low-resistance element. It will be noted that, at low frequencies, represented by the arrow C, the response is less than it is for intermediate frequencies, and that the response falls off materially at higher frequencies in the neighborhood of the arrow D. When a properly proportioned inductor is inserted in series with the damper winding, the impedance of the winding to high frequencies is increased, with a consequent reduction in the eddy currents and a decrease in the damping. The damping being decreased at the higher frequencies, the velocity of the diaphragm is permitted to increase somewhat at such frequencies, resulting in a proportionate increase in output voltage from the movable coil. The increase is represented by the dotted portion of the curve, E—F, showing that the effect of the diaphragm mass at the high frequencies is offset by the reaction of the eddy currents.

I have established by research and experiment that the response curve of the system will have the most desirable contour if the inductance of the coil in series with the damper-winding is so chosen that: $L=1/2(M)\ R$, where R is the ohmic resistance of the damper coil and $\frac{(M)}{(r)}$ is the ratio of total mass in motion to the damping at the low frequencies where L does not materially reduce the flow of eddy currents.

In the modification of my invention illustrated in Fig. 3, a single coil 21, which is supported on an insulating form 22 carried by the diaphragm 5, serves both as a generator and a damping device. The coil is connected in series with a resistor 23, as shown in Fig. 5, the resistance thereof being small in comparison with that of the coil. If the coil has ten times the resistance of the resistor, the voltage drop across the latter will be only one tenth of the drop within the coil, provided the frequencies are not so high that the inductance of the coil must be considered.

The primary 24 of the audio-frequency transformer is variably connected in shunt to the resistor 23, the secondary of the transformer being included in the input circuit of a suitable amplifier (not shown).

The total current flowing in the coil 21, and consequently its damping effect on the motion of the coil in the magnetic field, is proportional to the velocity of the diaphragm. The voltage across the resistor 23 is also proportional to the velocity of motion, if the primary impedance of the transformer 24—25 is high compared to the resistor.

By suitably proportioning the amount of the resistor included in shunt to the primary 24, the potential across the primary 24 may be adjusted to the best value, thus enabling the output volume of the amplifier associated with the secondary 25 to be controlled without interfering with the damping of the microphone diaphragm.

A microphone constructed and arranged according to my invention gives an output that is substantially free from distortion over the entire range of sound-frequencies necessary for natural reproduction. It is extremely simple in construction and relatively inexpensive to manufacture.

Many other advantages of my invention will be at once apparent to those skilled in the art, as will also numerous modifications thereof. My invention, therefore, is not to be limited except insofar as is necessitated by the prior art, or by the spirit of the appended claims.

I claim as my invention:

1. In a vibratory system, a magnetic field, a vibratory member, means for vibrating said member in said field to produce an electromotive force, an additional member arranged to be vibrated in said field by said means to produce a damping force proportional to the velocity of said vibrations, and means whereby the currents induced in said second member are prevented from adversely influencing the electromotive forces generated in said first named member.

2. In a vibratory system, a magnetic field, a vibratory member, means for vibrating said member in said field to produce an electromotive force, an additional member arranged to be vibrated in said field by said means to produce a damping force proportional to the velocity of said vibrations, and means for shielding said first named member against inductive effects caused by currents induced in said second named member by virtue of said vibratory motion.

3. In a vibratory system, a magnetic field, a vibratory member, means for vibrating said member in said field to produce an electromotive force, an additional member arranged to be vibrated in said field by said means to produce a damping force proportional to the velocity of said vibrations, and means inductively associated with both of said members for preventing electrical interaction therebetween.

4. In a vibratory system, a magnetic field, a plurality of vibrating members, means for vibrating said members in said field to produce electromotive forces, and means for rendering the velocity of said members truly proportional to the force acting on said first named means and independent of the frequency thereof over a wide range.

5. In a vibratory system, a magnetic field, a vibratory member, means for vibrating said member in said field to produce an electromotive force, means arranged to be vibrated in said field to produce a damping force proportional to the velocity of vibration, and additional means for decreasing said damping force at high frequencies.

In testimony whereof, I have hereunto subscribed my name this 28th day of October, 1927.

CLINTON R. HANNA.