Dec. 13, 1949 H. F. OLSON 2,491,390

ELECTRONIC TRANSDUCER

Filed Oct. 31, 1946 2 Sheets-Sheet 1

Fig. 1.

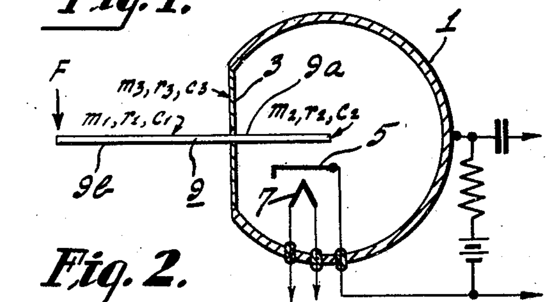


Fig. 2.

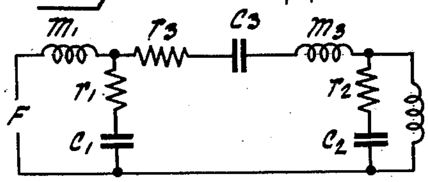


Fig. 3.

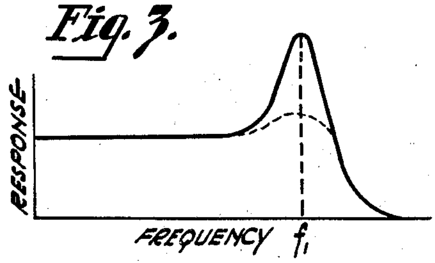


Fig. 4.

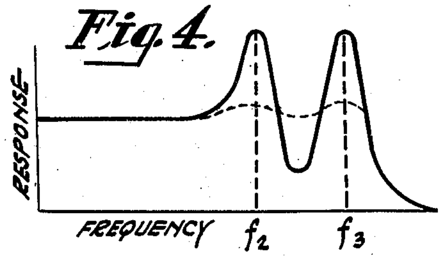


Fig. 5.

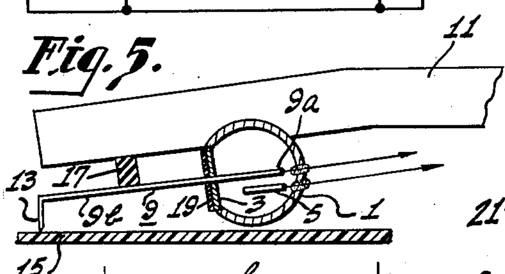
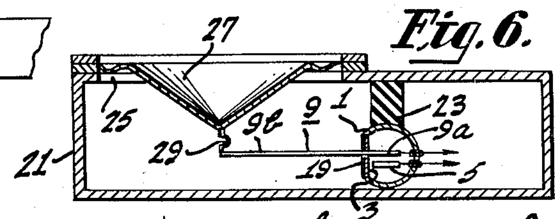
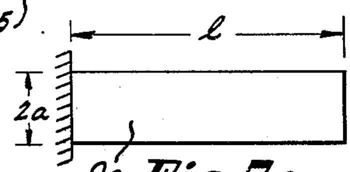


Fig. 6.





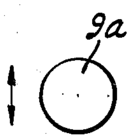
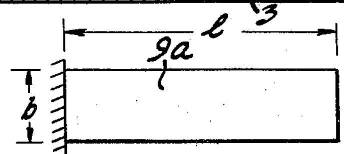


Fig. 7a. Fig. 7b.



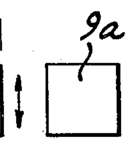
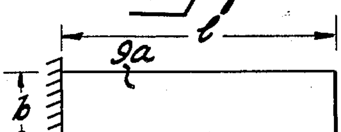


Fig. 8a. Fig. 8b.



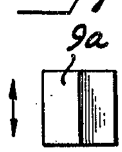
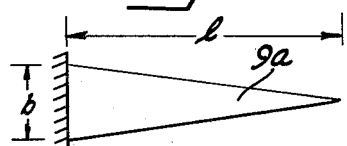


Fig. 9a. Fig. 9b.



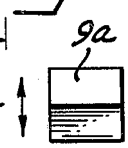
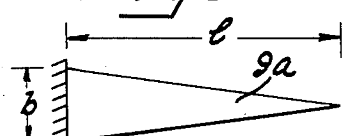


Fig. 10a. Fig. 10b.



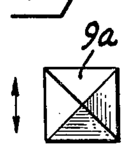
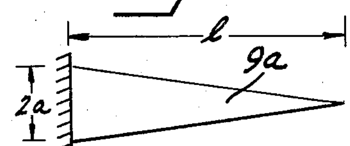


Fig. 11a. Fig. 11b.



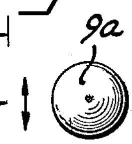


Fig. 12a. Fig. 12b.

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Fig. 13.

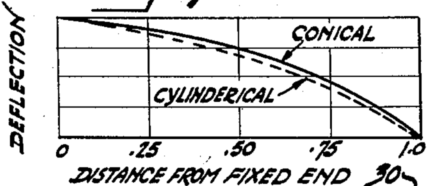


Fig. 14.

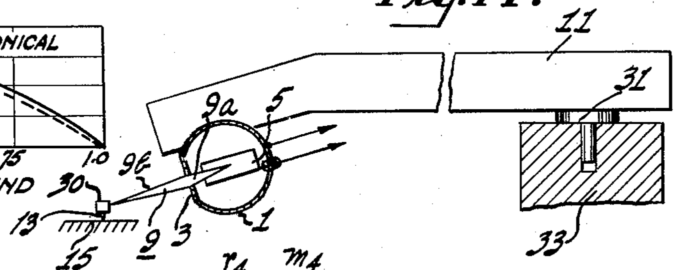


Fig. 15.

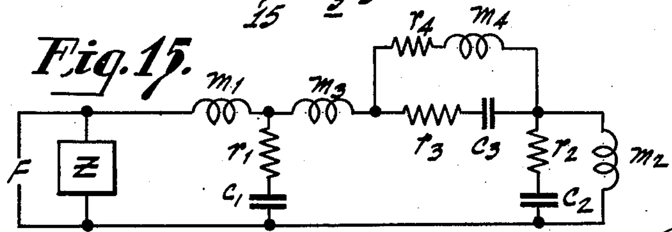


Fig. 16.

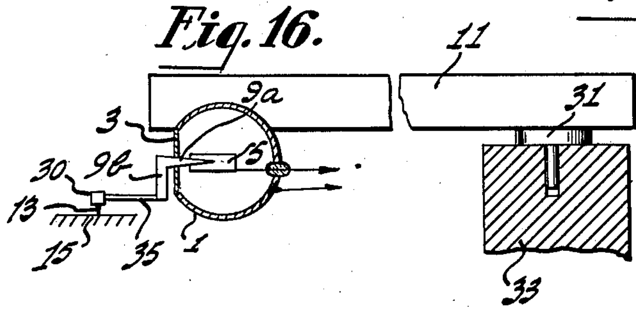


Fig. 17.

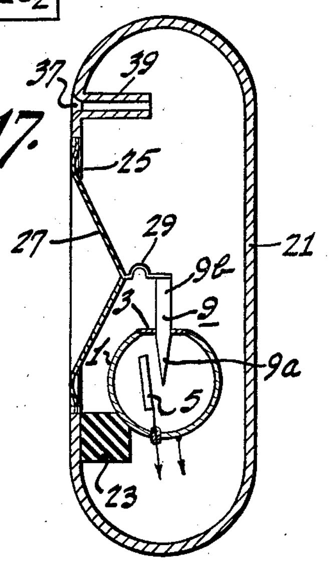
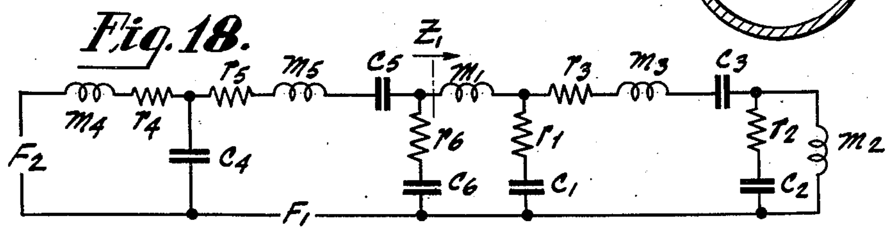


Fig. 18.



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Patented Dec. 13, 1949 2,491,390

UNITED STATES PATENT OFFICE

2,491,390

ELECTRONIC TRANSDUCER

Harry F. Olson, Princeton, N. J., assignor to Radio Corporation of America, a corporation of Delaware

Application October 31, 1946, Serial No. 706,967

12 Claims. (Cl. 250—27.5)

1

This invention relates to electronic transducers, and more particularly to a transducer suitable for reproduction of sound from a phonograph record.

Many types of electrical pick-up devices for use with phonograph records have been suggested heretofore, among them electronic devices employing an evacuated tube or shell having two or more electrodes therein one of which, such as the anode or the grid, is arranged to be movable relative to the others and has coupled thereto a phonograph needle. When the needle is actuated by the signal groove of a record, it actuates the coupling means between it and the aforesaid movable electrode to move the latter and thereby produce in the output circuit of the tube variations in current corresponding to the recorded signals. In spite of a number of advantages afforded by pick-up devices of this sort, one very important reason why such pick-up devices have not been put into commercial use is that difficulty is encountered in transferring the vibrations through a vacuum tight shell such as is necessary in devices of this sort. Within the tube or shell, there is a vacuum, while on the outside there is ambient air pressure. The differential in pressure is therefore approximately fifteen pounds per square inch. Now, the actuating forces encountered in the reproduction of sound from phonograph records are of the order of a millionth of a pound. To provide a vacuum tight link between the needle and the movable electrode within the tube or shell that can be actuated by forces of such small magnitude and that will withstand fifteen pounds per square inch of static pressure is a problem which long confronted the art without successful solution to a point where a commercial electronic pick-up device has been feasible.

Aside from the foregoing, my investigations have shown that consideration must be given to the vibrating system of such a transducer if it is to be operated at suitable efficiency. The voltage developed by the electronic generating system of the type under consideration is proportional to the amplitude of vibration of the vibratile electrode. Therefore, to maintain constant voltage output over a certain frequency band, the amplitude of vibration must be independent of the frequency over that frequency range. Under these conditions, the velocity is proportional to the frequency and if the system is mass controlled the mechanomotive force will be proportional to the square of the frequency. Due to these factors, namely, the constant amplitude requirement and the square of the frequency function for the mechanomotive force, it is evident that the mechanical mass reactance will govern the ultimate sensitivity of any system in which the available driving force is limited or fixed. For this reason, it is extremely important that the effective mass

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of the driving link in the electronic transducer be made as small as possible.

The primary object of my present invention, then, is to provide an improved electronic transducer of the type under consideration in which the driving link or rod between the source of the driving force and the movable or vibratile electrode will have a small mechanical mass reactance.

More particularly, it is an object of my present invention to provide an improved electronic transducer which is suitable for use in phonograph pick-ups, microphones, and other similar devices, and which will operate with maximum efficiency.

Another object of my present invention is to provide an improved electronic transducer which can be replaced easily without requiring the service of one with technical training.

A further object of my present invention is to provide an improved electronic transducer which will not be affected by temperature or humidity changes.

Still another object of my present invention is to provide an improved electronic transducer as above set forth which will have an electrical impedance that renders it particularly suitable for use as an electric pick-up device for phonographs in contrast to the relatively high impedance which characterizes so-called crystal pick-ups and the low impedance of so-called magnetic pick-ups from the standpoints of transmission and electrical noise pick-up.

It is also an object of my present invention to provide an improved electrical transducer as aforesaid which can be manufactured easily, which will be practically free from trouble in use, and which will be very efficient for the purposes to which it may be applied.

In accordance with my present invention, the transducer consists, essentially, of an evacuated vessel, such as a metal tube envelope, one wall of which, such as the base, is constituted by a thin, metallic diaphragm. The tube may be a diode, in which case the plate or anode is arranged to be the movable electrode, or it may be a triode, a pentode or any other suitable type of multi-electrode tube, in which case the grid may constitute the movable electrode. In any case, the movable electrode is mounted on the aforesaid diaphragm which constitutes a flexible support therefor. Also coupled to the diaphragm is an actuating link which, in the case of a phonograph pick-up, may carry or be coupled to a phonograph needle, or in the case of a microphone, may be coupled to a suitable vibratory diaphragm adapted to be set in vibration by sound waves impinging thereon.

The movable electrode, whether the anode of a diode or the grid of a triode or the like, will be referred to hereinafter as the control electrode. This control electrode should preferably extend in a direction generally parallel to that of the cathode or electron emitting electrode. The control electrode may be of various cross sections, as will appear more fully hereinafter, but I have found from my investigations that a control electrode which is tapered, and preferably conical, with its base end secured to the diaphragm wall of the envelope or shell provides best results.

The novel features of my invention, as well as additional objects and advantages thereof, will better be understood from the following description of several embodiments thereof, when read in connection with the accompanying drawings in which

Figure 1 is a view partly in section and partly diagrammatic showing, generally, one form of transducer in accordance with my present invention,

Figure 2 is a wiring diagram showing the electrical analogue of the mechanical network of Figure 1,

Figure 3 is a curve showing the response frequency characteristic of the form of my invention shown in Figure 1 when the vibratory bar or rod is stiff and its mechanical resistance is small, the solid line curve showing the characteristic without damping, and the dotted line curve showing the characteristic with damping,

Figure 4 is a similar curve in which all the elements of the vibrating system are effective in the response range, the mechanical resistances of the various parts of the system being small,

Figure 5 is a side elevation, partly in section, of one form of pick-up device for use with phonograph records in accordance with my present invention,

Figure 6 is a sectional view of one form of microphone in accordance with my present invention,

Figures 7*a*—12*a*, inclusive, are graphic views of cantilever bars of various configurations showing the various forms in which the control electrode of my present invention may be made,

Figures 7*b*—12*b* are end views thereof as seen from the right of each of Figures 7*a*—12*a*,

Figure 13 is a graph showing the deflection of a conical and a cylindrical control electrode such as illustrated in Figures 7*a*, 7*b*, and 12*a*, 12*b*,

Figures 14 and 16 are side elevations, partly in section, of other forms of phonograph pick-up devices according to my present invention,

Figure 15 is a wiring diagram showing the electrical analogue of the vibratory systems of Figures 14 and 16,

Figure 17 is a sectional view of another form of microphone in accordance with my present invention, and

Figure 18 is a wiring diagram showing the electrical analogue of the mechanical network of the vibratory system of the microphone of Figure 17.

Referring more particularly to the drawings wherein similar reference characters indicate corresponding parts throughout, there is shown, in Figure 1, an evacuated vessel comprising a metallic shell **1** having an opening in the wall structure which is closed by a thin, flexible, metallic diaphragm **3**. Within the shell or vessel **1** is a cathode **5** which may be heated by a filament **7**, and an anode **9***a* which is constituted by the inner portion of an elongated rod or bar **9** which extends through and is secured to a flexible diaphragm **3**, the rod **9** having a portion **9***b* which is external to the vessel **1**. It is apparent, therefore, that since the bar or rod **9** is anchored at the diaphragm **3**, its inner portion (that is, the

anode **9***a*) may be considered as a cantilever bar one end of which is anchored at the diaphragm and the other end of which is freely suspended within the shell **1**.

The structure thus far described represents the fundamental vibrating system for transferring vibrations through the vacuum tight shell **1**. The mechanical network of the vibrating system of Figure 1 is shown in Figure 2 wherein F represents the driving force applied at the outer end of the rod portion **9***b*; m_1, r_1, and c_1 represent, respectively, the effective mass, the mechanical resistance and the compliance of the rod portion **9***b*; m_2, r_2, and c_2, respectively represent the effective mass, the mechanical resistance and the compliance of the anode or internal portion 9*a* of the rod **9**; and m_3, r_3, and c_3, respectively represent the effective mass, the mechanical resistance and the compliance of the diaphragm **3**. The damping in the metallic system of Figure 1 is practically negligible and for this reason the response will be extremely high at the resonant frequencies of the coupled system. By suitable selection of constants, either or both of the resonant frequencies of the rod portions **9***a* and **9***b* may be located inside or outside of a prescribed frequency band.

The response frequency characteristic of an electronic transducer such as shown in Figure 1 and in which the bar **9** has a very high stiffness is shown by the solid line curve of Figure 3. In this case, the effect of the compliances c_1 and c_3 are negligible in the frequency range under consideration. For this condition, there is only one resonant frequency at the frequency f_1. The ratio of the amplitude to the force is independent of the frequency below the resonant frequency. A transducer of the type shown in Figure 1 in which all the elements of the vibrating system are effective in the selected response range is shown by the solid line curve of Figure 4. Here, it will be noted that there are two peaks at the frequencies f_2 and f_3. The sharp peaks in the response range are undesirable and must be damped in transducers used in the reproduction of sound. The mechanical system outside the shell **1** may be damped, if desired, by the application of damping material to the rod portion **9***b* and also to the diaphragm **3**, as will be described more fully hereinafter with reference to Figure 5. If desired, also, the rod **9** may be made of hollow tubing with damping material within it. The response frequency characteristics will appear as shown by the dotted line curves of Figures 3 and 4 when damping is applied. In the latter case, the mechanical resistances are relatively large.

In Figure 5, there is shown a pick-up device utilizing the features of my invention discussed above. Here, the metallic shell or vessel **1** is secured to a pick-arm arm **11** and the rod portion **9***b* is provided at its free, outer end with a needle **13** for cooperation with a phonograph record **15**. A block of damping material **17**, such as rubber or Viscaloid, is interposed between the rod portion **9***b* and the arm **11**, and the strip or pad of similar damping material **19** is applied to the diaphragm **3**.

In Figure 6, there is shown a microphone utilizing an electronic transducer as above described. This microphone has a casing **21** within which the shell or vessel **1** is supported by means of a supporting block **23**. The casing **21** has an opening **25** therein over which is mounted an acoustic diaphragm **27** for vibration in response to sound waves impinging thereon. The diaphragm **27** may be coupled to the free end of the rod portion 9b by means of a compliant link 29.

In all of the above modifications, the rod or bar 9, including its anode portion 9a, is of cylindrical form. In wide range transducers, it is desirable to make the effective mass reactance of the anode portion 9a as small as possible. This can be accomplished in accordance with my present invention by utilizing bars or rods of tapered cross section since such bars will exhibit a higher resonant frequency for the same effective mass, or a smaller effective mass for the same resonant frequency.

As will be obvious from an inspection of Figures 1, 5 and 6, the anode portion 9a of the bar 9 constitutes a cantilever bar with respect to the diaphragm 3 on which it is supported. The fundamental resonant frequency, in cycles per second, of a cantilever bar of uniform, circular cross section as shown in Figures 7a and 7b (that is, a cylinder) is given by the equation

$$f=\frac{.56}{l^2}\sqrt{\frac{Qa^2}{4\rho}} \qquad (1)$$

where

l=length of the bar, in centimeters,
a=radius of the bar, in centimeters,
Q=Young's modulus, in dynes per square centimeter, and
ρ=density, in grams per cubic centimeter.

The fundamental resonant frequency of a bar with uniform rectangular cross section, as shown in Figures 8a and 8b, is given by the equation.

$$f=\frac{.56}{l^2}\sqrt{\frac{Qb^2}{12\rho}} \qquad (2)$$

where

b=thickness of the bar in the direction of vibration, in centimeters.

The resonant frequency of a wedge shaped bar vibrating in a direction normal to the two parallel sides of the wedge, as in Figures 9a and 9b, is given by the equation

$$f=\frac{1.14}{l^2}\sqrt{\frac{Qb^2}{12\rho}} \qquad (3)$$

where

b=thickness of the bar in the direction of vibration, in centimeters.

The resonant frequency of a wedge shaped bar vibrating in a direction parallel to the two parallel sides of the wedge, as illustrated in Figures 10a and 10b, is given by the equation

$$f=\frac{.85}{l^2}\sqrt{\frac{Qb^2}{12\rho}} \qquad (4)$$

The resonant frequency of a pyramidal bar with a square base vibrating in a direction parallel to the base, as shown in Figures 11a and 11b, is given by the equation

$$f=\frac{1.20}{l^2}\sqrt{\frac{Qb^2}{12\rho}} \qquad (5)$$

where

b=length of the base along any side thereof, in centimeters.

The resonant frequency of a conical bar, such as shown in Figures 12a and 12b, is given by the equation

$$f=\frac{1.39}{l^2}\sqrt{\frac{Qa^2}{4\rho}} \qquad (6)$$

where

a=radius of the cone at the base, in centimeters.

The resonant frequency of a hollow, cylindrical pipe (not illustrated) is given by the equation

$$f=\frac{.56}{l^2}\sqrt{\frac{Q(a^2+a_1^2)}{4\rho}} \qquad (7)$$

where

a=outside radius of the pipe, in centimeters, and
a_1=inside radius of the pipe, in centimeters.

A consideration of the above equations shows that, for a certain resonant frequency, the conical bar of Figures 12a and 12b will yield the lowest effective mass. If the fundamental resonant frequency of the cylindrical bar of Figures 7a and 7b is made the same as the conical bar of Figures 12a and 12b, the ratio of their radii for the same length will be

$$\text{Ratio}=\frac{\text{Radius of cylindrical bar}}{\text{Radius at base of conical bar}}=\frac{1.39}{.56}=2.5 \qquad (8)$$

The ratio of the total masses of the two bars under these conditions will be

$$\text{Ratio}=\frac{\text{Total mass of cylindrical bar}}{\text{Total mass of conical bar}}=\frac{(2.5)^2}{.33}=19 \qquad (9)$$

The mass referred to the free, inner end of the anode portion 9a of the bar is termed the "effective mass." In the case of the electronic transducer, when the compliance of the diaphragm 3 is very large compared to the compliance of the rod 9, and in the frequency below the resonant frequency of the rod 9, the rod moves as a rigid member with the diaphragm 3 as a fulcrum. The effective mass of the cylindrical bar under these conditions is given by the equation

$$m_{EU}=\frac{2KE}{\dot{\delta l}^2} \qquad (10)$$

where

KE=kinetic energy stored in the bar, and
$\dot{\delta l}$=velocity at the end of the bar.

The effective mass may be expressed as

$$m_{EU}=\int_0^l\left(\frac{x}{l}\right)^2 m_1\cdot dx \qquad (11)$$

$$=\frac{1}{3}lm_1=\frac{1}{3}m_U \qquad (12)$$

where

m_1=mass per unit length, and
m_U=total mass of the bar 9a.

The effective mass of a cylindrical bar 9a with the base as a fulcrum is ⅓ the total mass of the bar.

The effective mass of a conical bar with the base as a fulcrum is

$$m_{EC}=\int_0^l \pi r^2\rho\left(\frac{x}{l}\right)^2\frac{(l-x)^2}{l^2}dx \qquad (13)$$

$$m_{EC}=\frac{\pi r^2\rho l}{30} \qquad (14)$$

where

ρ=density of the material in the bar.

The total mass of the bar is

$$m_C=\frac{1}{3}\pi r^2\rho l \qquad (15)$$

Then

$$m_{EC}=\frac{1}{10}m_C \qquad (16)$$

The effective mass of a conical bar with the base as a fulcrum is 1/10 the total mass of the bar.

For the same fundamental resonant frequency, the ratio of the effective masses, from Equations 9, 12 and 16, will be

$$\frac{m_{EU}}{m_{EC}}=63 \qquad (17)$$

This means that below the resonant frequency, where the vibrating system is governed by the mass, the mechanical reactance for the conical bar will be

$$\frac{1}{63}$$

that of the cylindrical bar. In the case of a system in which the mass of the vibrating bar is the controlling mechanical reactance, the sensitivity will be increased approximately 36 db. by the use of the conical bar. In the case of the phonograph pick-up, the mechanical reactance presented to the record may be reduced by the factor of 63 to 1.

The deflection of a cylindrical bar at resonance with reference to its neutral or static position is given by the equation

$$\delta x=\frac{4\delta l}{l^4}\left[\frac{l^2x^2}{2}-\frac{lx^3}{3}+\frac{x^4}{12}\right] \qquad (18)$$

where

x=distance along the bar portion **9**a from the diaphragm **3**.

The deflection of a conical bar at resonance is given by

$$\delta x=\delta l\frac{x^2}{l^2} \qquad (19)$$

The deflection curves for cylindrical and conical bars are shown in Fig. 13. It is interesting to note, in passing, that the difference between the deflection characteristics is very small. At resonance, the effective mass of the cylindrical bar is

$$m_{EUR}=\int_0^l\frac{16m_l}{8}\left[\frac{l^2x^2}{2}-\frac{lx^3}{3}+\frac{x^4}{12}\right]dx \qquad (20)$$

$$=.25m_l l=.25m_U \qquad (21)$$

At resonance, the effective mass of a conical bar is

$$m_{ECR}=\int_0^l\pi r^2\rho\frac{(l-x)^2}{l^2}\frac{x^4}{l^4}dx \qquad (22)$$

$$=\frac{m_C}{35}=.0285m_C \qquad (23)$$

For the same resonant frequency, the ratio of the effective masses from Equations 9, 21 and 23 is

$$\frac{m_{EUR}}{m_{ECR}}=166 \qquad (24)$$

The relative effective masses at resonance are in the ratio of 166:1. A small effective mass at resonance is extremely important not only from the standpoint of sensitivity but from the standpoint of damping as well. The mechanical resistance required for the same response characteristic is also in the ratio of 166:1. This means that the problem of damping is tremendously simplified in the case of the conical bar.

In the preceding analysis, it has been shown that the effective mass of a conical bar is 1/63 the effective mass of a cylindrical bar below the resonant frequency of the bar and that, at the

resonant frequency, the effective mass of the conical bar is

$$\frac{1}{166}$$

the effective mass of a cylindrical bar. The advantage of making the rod portion **9** conical will be readily apparent. Other tapered bars, such as those of Figures 9a, 10a and 11a also offer a marked advantage over the cylindrical bar of Figure 7a and the rectangular bar of Figure 8a. However, the conical bar or rod of Figure 12a provides best results.

In Figure 14, I have shown another form of phonograph pick-up device according to my present invention and in which the anode portion **9**a of the bar which is supported by the diaphragm **3** is in the form of a cone. Preferably, also, the external portion **9**b of the bar **9** is in the form of a cone which tapers oppositely to the anode portion **9**a within the shell **1**. The outer or tip portion of the bar section **9**b carries a socket **30** in which the phonograph needle **13** is mounted. The arm **11** may be pivotally supported for swinging movement over the record **15** on an oiled bearing **31** which is, in turn, carried by a suitable support **33**.

Figure 16 shows a modification of the electrical pick-up device of Figure 14. In Figure 16, the anode portion **9**a is also a cone, but instead of extending the rod **9** outwardly from the anode portion **9**a in axial alignment therewith, the portion **9**b extends downwardly and has connected thereto at its lower end, a wire element **35** which may be of the type shown, for example, in the Hasbrouck Patent No. 2,326,460 and which carries the phonograph needle **13** at its outer end. This modification of my invention permits arranging the envelope **1** of the transducer horizontally (that is, with the axis of the diaphragm **3** horizontally) and this, in turn, permits a reduction in the vertical dimensions of the pick-up arm **11**. The mechanical network of the arrangements of Figures 14 and 16 is illustrated in the wiring diagram of Figure 15 where F is the force applied at the needle **13**; Z represents the mechanical impedance of the record **15**; m_1 represents the mass of needle **13** and its socket **30**, the rod portion **9**b (and in the case of Figure 16, also the wire element **35**); r_1 and c_1 represent, respectively, the mechanical resistance and the compliance of the portion of the vibrating system external to the shell **1**; m_2, r_2 and c_2 represent, respectively, the mass, the mechanical resistance and the compliance of the rod portion or anode **9**a; m_3, r_3 and c_3 represent, respectively, the mass, the mechanical resistance and the compliance of the diaphragm **3**; and m_4 and r_4 represent, respectively, the mass of the pick-up arm **11** and the resistance at the pivot **31**.

In Figure 17, there is shown another form of microphone employing a transducer in accordance with my present invention. The microphone of Figure 17 is generally similar to that shown in Figure 6 except that the case **21** is here provided with a second opening **37** in its front wall adjacent the opening **25** and with an inwardly directed tube **39** leading from the opening **37**. The opening **37** and tube **39** provide a small port or vent which introduces an additional degree of freedom and makes it possible to accentuate the response at the low frequency portion of the selected frequency range, and at the same time to obtain a sharp, low frequency cut-off.

Figure 18 shows an electric wiring diagram which is the analogue of the mechanical system of the microphone of Figure 17. The two driving forces F_1 and F_2 are equal and opposite in phase. The driving force F_1 is given by the equation

$$F_1 = p_1 A_D \tag{25}$$

where

A_D=the area of the diaphragm **27**, and
p_1=the sound pressure at the diaphragm **27**.

The driving force F_2 is given by the equation

$$F_2 = p_2 A_D \tag{26}$$

where

A_D=the area of the diaphragm **27**, and
p_2=the sound pressure at the port **37**, **39**.

Referring further to Figure 18, Z_1 represents the mechanical impedance of the electronic transducer; m_1, r_1 and c_1 again represent, respectively, the mass, the mechanical resistance and the compliance of the external rod portion **9b** of the transducer; m_2, r_2 and c_2 represent, respectively, the mass, the mechanical resistance and the compliance of the internal portion or anode **9a** of the transducer; m_3, r_3 and c_3 represent, respectively, the mass, the mechanical resistance and the compliance of the diaphragm **3**; m_4 and r_4 represent, respectively, the mass and mechanical resistance of the air in the port **37**, **39**; c_4 represents the compliance of the air within the casing **21**; m_5, r_5 and c_5 represent, respectively, the mass, the mechanical resistance and the compliance of the diaphragm **27**; and r_6 and c_6 represent, respectively, the mechanical resistance and the compliance of the link **29**.

At the high frequencies, the mechanical reactance due to the compliance c_4 is small compared to the mechanical impedance of the port **37**, **39** (that is, m_4, r_4). Under these conditions, the system is driven by the force F_1. At the extreme low frequencies, the mechanical reactance of the compliance c_4 is large compared to the mechanical impedance of the port **37**, **39** (again, m_4, r_4) and since F_1 and F_2 are of opposite phase, the net driving force is practically zero. In the region where the mechanical reactance due to the compliance c_4 and the mechanical reactance due to the port **37**, **39** (or m_4, r_4) are comparable, the addition of this network introduces a phase shift of such magnitude that both F_1 and F_2 contribute in driving the mechanical system.

An electronic microphone of this type is an extremely simple device. It consists of the electronic transducer, a sound wave responsive diaphragm, and the case. For this reason, the cost should be very low. A microphone of this type would be suitable for sound reinforcing systems, public address systems, call and paging systems, outside broadcast pick-up, amateur radio, home recording, and many other uses. Because of its low cost and its high output, an electronic microphone of this sort is advantageous for general sound applications, particularly since a microphone of this sort can be made to have the same sensitivity as the carbon microphone but without the disadvantages of high distortion, carbon packing and variation of response with orientation inherent in the carbon microphone, while at the same time possessing the good articulation characteristic of dynamic or magnetic microphones.

Although I have shown and described several embodiments and applications of my present invention, it will undoubtedly be apparent to those skilled in the art that many other forms thereof and applications therefor are possible. I therefore desire that the foregoing description shall be taken merely as illustrative and not as limiting.

I claim as my invention:

1. An electronic transducer comprising an evacuated vessel having a flexible diaphragm as part of its wall structure, and a plurality of electrodes therein one of which is fixed and is adapted to emit electrons and another of which joins and is mounted on said diaphragm and extends therefrom in a direction generally parallel to said one electrode in spaced relation thereto, said other electrode being of tapered configuration in the direction of extension from the diaphragm and being movable toward and away from said one electrode upon flexure of said diaphragm.

2. An electronic transducer comprising an evacuated vessel having a flexible diaphragm as part of its wall structure, and a plurality of electrodes therein one of which is adapted to emit electrons and another of which is of tapered configuration and is mounted on said diaphragm at its largest cross section, said other electrode extending in a direction generally parallel to that of said one electrode in spaced relation thereto and being movable toward and away from said one electrode upon flexure of said diaphragm.

3. An electronic transducer comprising an evacuated vessel having a flexible diaphragm as part of its wall structure, and a plurality of electrodes therein one of which is adapted to emit electrons and another of which is mounted on said diaphragm for movement toward and away from said one electrode upon flexure of said diaphragm to thereby control the flow of electrons toward itself, said other electrode comprising a conical member extending in a direction generally parallel to that of said one electrode in spaced relation thereto.

4. An electronic transducer comprising an evacuated vessel having a flexible diaphragm as part of its wall structure, and a plurality of electrodes therein one of which is adapted to emit electrons and another of which is mounted on said diaphragm for movement toward and away from said one electrode upon flexure of said diaphragm to thereby control the flow of electrons toward itself, said other electrode comprising a conical member extending in a direction generally parallel to that of said one electrode in spaced relation thereto and being connected to said diaphragm at its base.

5. An electronic transducer according to claim 2 characterized in that said other electrode is of gradually converging taper in a direction away from said diaphragm.

6. An electronic transducer according to claim 2 characterized in that said other electrode comprises a wedge-shaped member.

7. An electronic transducer according to claim 2 characterized in that said other electrode comprises a pyramid.

8. An electronic transducer according to claim 2 characterized in that said other electrode extends through said diaphragm, and characterized by the addition of means coupled to the portion of said other electrode which is external to said vessel for imparting vibrations to said other electrode upon application of forces to said means.

9. An electronic transducer comprising an evacuated vessel having a flexible diaphragm as part of its wall structure, a first electrode therein adapted to emit electrons, a second electrode therein of tapered configuration secured at its base to said diaphragm and extending inwardly

from said diaphragm generally in a direction parallel to said first electrode in spaced relation thereto, said second electrode being movable toward and away from said first electrode upon flexure of said diaphragm to thereby control the flow of electrons toward itself, and means connected to said diaphragm external to said vessel for effecting flexure thereof whereby to move said second electrode relative to said first electrode.

10. An electronic transducer according to claim 9 wherein said means includes a phonograph needle adapted to cooperate with a phonograph record.

11. An electronic transducer according to claim 9 wherein said means includes a second and vibratory diaphragm adapted to be set into vibration by acoustical waves impinging thereon.

12. A low mass, light weight transducer unit for use in electronic phonograph pickups and the like, comprising a relatively small electronic tube shell having an opening in the wall structure thereof, a thin flexible diaphragm providing closure means sealing said opening, a fixed cathode element in said shell, a tapered control electrode fixed at its base to said diaphragm and extending inwardly therefrom in spaced relation to said cathode element, said control electrode having an extension element secured to said diaphragm externally of said shell for imparting movement to said control electrode with respect to the fixed electrode in response to an applied force of a magnitude to flex said diaphragm, said control electrode and extension thereof having a relatively low moment of inertia about the connection with the diaphragm and a relatively small mechanical mass reactance, and means providing electrical connections with said fixed cathode element and movable control electrode externally of said shell.

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