

July 9, 1935.

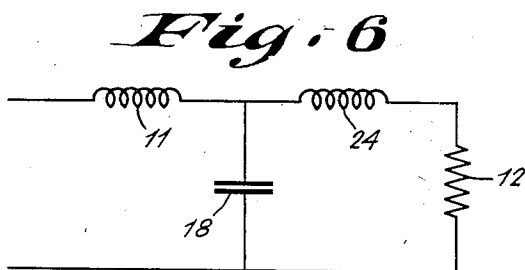
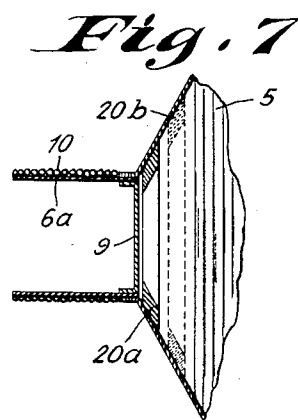
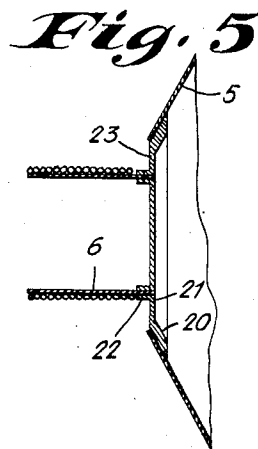
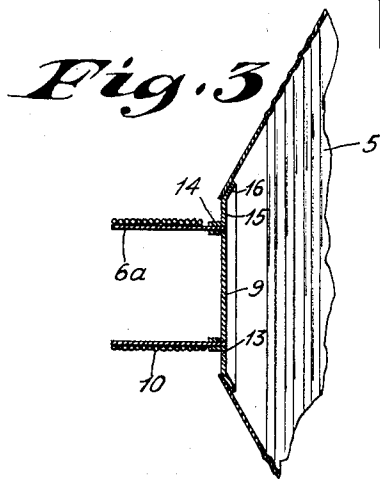
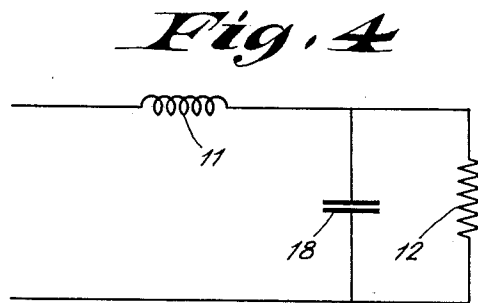
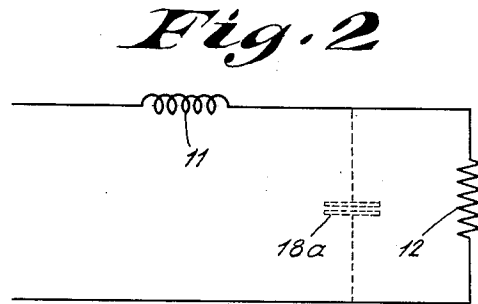
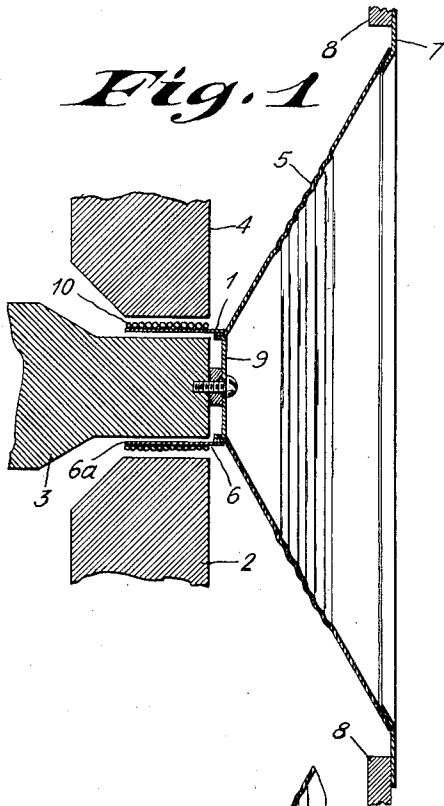
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2,007,750

ACOUSTIC APPARATUS

Filed Jan. 11, 1934

3 Sheets-Sheet 1



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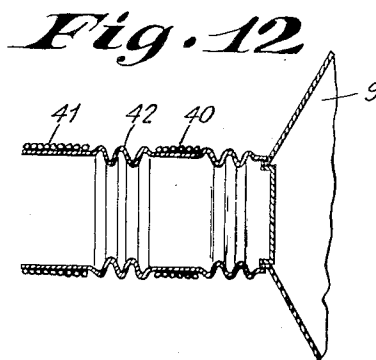
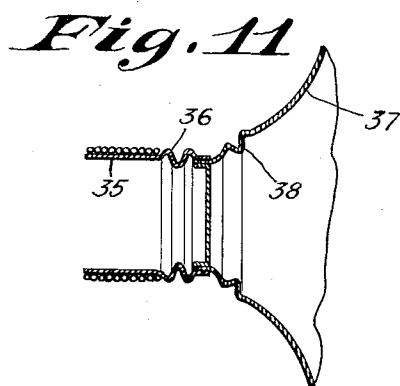
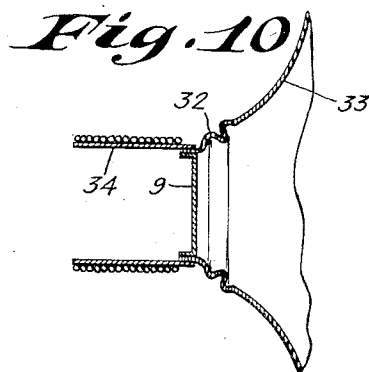
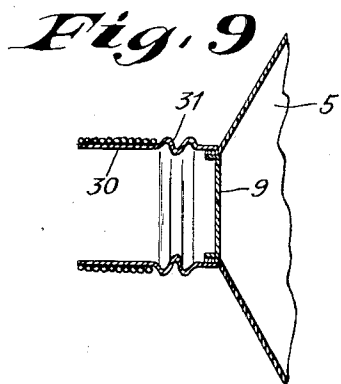
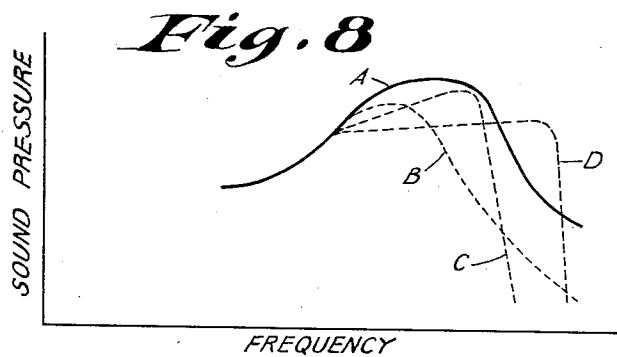
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ACOUSTIC APPARATUS

Filed Jan. 11, 1934

3 Sheets-Sheet 2



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ACOUSTIC APPARATUS

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3 Sheets-Sheet 3

Fig. 13

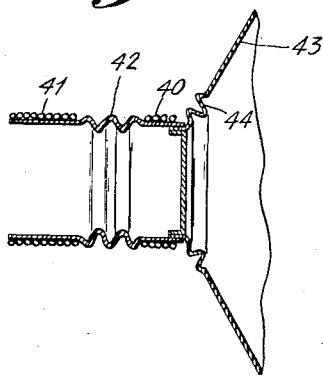


Fig. 14

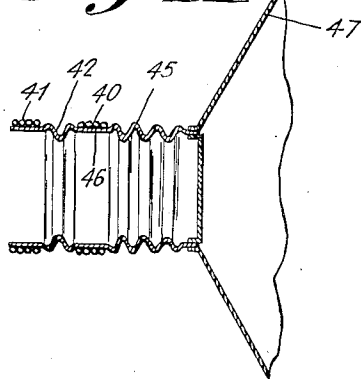


Fig. 15

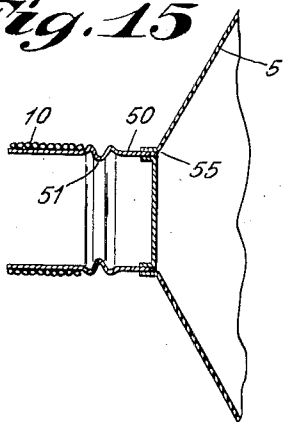


Fig. 17

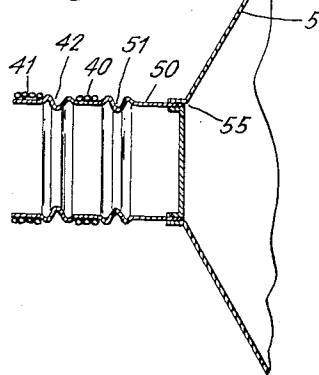


Fig. 16

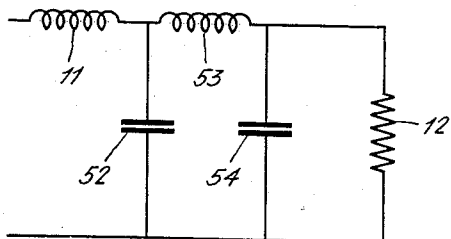
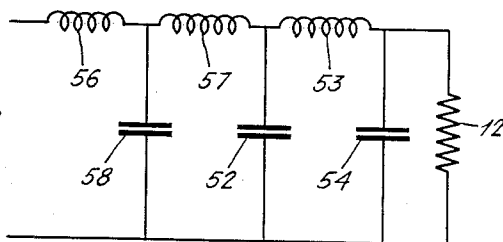


Fig. 18



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ACOUSTIC APPARATUS

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Application January 11, 1934, Serial No. 706,195

9 Claims. (Cl. 179—115.5)

This invention relates to acoustic apparatus. More particularly, the invention relates to acoustic apparatus such as loudspeakers of the electro-dynamic or moving coil type in which the moving coil is associated with the diaphragm in such a way as to provide a desired control over the high frequency response of the device.

It is the object of the invention to provide a new and improved vibratile system for acoustic apparatus of the electro-dynamic or moving coil type. More specifically, the object of the invention is to provide a mechanical filter in the vibratile system between the part of the system where the driving forces are applied and the part of the system where the sound waves are set up. The filter is of such a nature as to permit control of the high frequency response of the device. It consists of a compliant connection between the voice coil form and the diaphragm and, in some instances, an addition of mass to a part of the system. The high frequency response of the acoustic device is controlled by varying the stiffness of the compliant connection and by varying the mass.

Other and more specific objects of the invention will become apparent upon reading the following specification and appended claims in connection with the accompanying drawings which illustrate various forms of apparatus embodying the invention.

In the accompanying drawings in which the same reference numerals are used to indicate like parts in the different modifications,

Fig. 1 is a cross sectional view of the vibratile system of an electro-dynamic loudspeaker of the type well known in the art.

Fig. 2 is the equivalent electrical circuit of the apparatus illustrated in Fig. 1.

Fig. 3 is a sectional view of the vibratile portion of an electro-dynamic loudspeaker which has been modified in accordance with the present invention.

Fig. 4 is the equivalent electrical circuit of the apparatus illustrated in Fig. 3.

Fig. 5 is a cross sectional view of a modification of the apparatus illustrated in Fig. 3.

Fig. 6 is the equivalent electrical circuit of the apparatus illustrated in Fig. 5.

Fig. 7 is a cross sectional view of another modification of the apparatus illustrated in Fig. 3.

Fig. 8 is a graph showing the characteristics of the apparatus of Figs. 1, 3 and 5.

Figs. 9 to 18 are cross sectional views and equivalent electrical circuits of apparatus em-

bodimenting modifications of the apparatus illustrated in Fig. 3.

The modern electrodynamic loudspeaker, as illustrated in Fig. 1, comprises a vibratile system indicated generally at 1 and a magnet system indicated at 2. The magnet system includes a central pole piece 3 and an outer pole piece 4 spaced therefrom to form an annular air gap in which a portion of the vibratile system is located. The vibratile system comprises a diaphragm or sound wave producing portion 5 and a driving portion 6. The sound wave producing portion is usually in the form of a truncated cone supported at its larger base by means of an annular rim of flexible material 7 secured to a suitable supporting member 8. The cone is supported at its smaller base by a spider member 9 which may be secured either to the inner pole piece 3, as shown in Fig. 1, or to the outer pole piece 4. The driving system 6 comprises a cylindrical coil form 6—a secured to the apex portion of the diaphragm adjacent the smaller base thereof, and a voice coil supported on the coil form. The voice coil terminates in leads (not shown) which extend to an external circuit.

The electrical circuit which is the equivalent of the mechanical apparatus illustrated in Fig. 1, is shown in Fig. 2. The circuit comprises the series connection of an inductor 11 and a resistor 12. The inductor 11 is the equivalent of the mechanical impedance of the voice coil 10 and the resistor 12 is the equivalent of the mechanical impedance of the cone 5.

Vibratile systems of the type illustrated in Fig. 1 are limited in their ability to reproduce high frequencies by the mass of the sound wave producing portion 5, the mass of the actuating portion 6 and by the type of mechanical connection between the sound wave producing portion and the actuating portion. In two copending applications filed respectively in the names of Abraham S. Ringel March 17, 1933, Serial No. 661,237 and Harry F. Olson June 1, 1933 Serial No. 673,823, methods for increasing the high frequency response by decreasing the effective mass of the driving coil system at high frequencies, are shown and described. The present application shows and describes various arrangements for controlling the high frequency response of an acoustic device by controlling the stiffness of the mechanical connection between the driving coil system and the diaphragm of the sound wave producing portion of the vibratile system.

Fig. 3 illustrates apparatus in which an improved form of the invention is embodied. Fig. 3

and subsequent figures show only the vibratile system, as the magnet system and the various supporting members do not constitute a part of the invention, and are not necessary for a complete understanding of the invention.

The vibratile system comprises a truncated cone 5, which forms the sound wave producing portion, and a driving portion 6 consisting of coil form 6-a and driving coil 10. Instead of connecting the coil form directly to the smaller base of the cone 5, a flexible connecting member 13 is interposed between the driving system and the diaphragm. The member 13 includes a short cylindrical collar portion 14 secured to the coil form, an annular portion 15 and a conical collar portion 16 secured to the diaphragm. The annular portion 15 may be a plain imperforate member of sufficient thickness to provide the desired flexibility or it may be perforated or embossed in any desired manner to increase its flexibility. Instead of using an annular member of the type described, a plurality of arms, either radial or non-radial, may be connected between the driving system and the diaphragm. The annular portion 15 of the member 13 comprises a compliant link between the sound wave producing portion 5 and the driving portion 6 of the vibratile system. The compliant link has the effect of diminishing the high frequency response in a manner desirable in certain instances in the reproduction of sound.

While the member 13 is shown in Fig. 3 as a separate and distinct member, it may be formed by a continuation of the diaphragm 5, or of the coil form 6-a, or of the spider member 9. It has also been found that in many instances the connection between the coil form and the diaphragm introduces sufficient flexibility into the system so that the connection itself constitutes a compliant connection between the driving system and the sound wave producing system. For example:—in the apparatus illustrated in Fig. 1, the connection between the coil form 6-a and the diaphragm 5 may introduce sufficient compliance into the system so that the desired results may be obtained without using a coupling member 13.

Fig. 4 shows an electrical circuit which is the equivalent of the apparatus illustrated in Fig. 3. The circuit includes an inductor 11 which is the equivalent of the mechanical impedance of the voice coil 10, a resistor 12 which is the equivalent of the mechanical impedance of the cone 5, and a capacitor 13 connected in parallel with the resistor 12. The capacitor which represents a capacity connected in parallel to the cone impedance, is the equivalent of the compliance introduced into the mechanical system by the connecting member 13. In Fig. 2 a capacitor 13-a is shown in dotted lines to represent the compliance which may be introduced into the apparatus of Fig. 1 solely by the nature of the connection between the voice coil form 6-a and the diaphragm 5.

Fig. 5 illustrates a modification in which a mass 20 is introduced into the vibratile system on the cone side of the coupling member. The coupling member which is indicated at 21, includes a cylindrical portion 22 similar to the cylindrical portion 14 of the coupling member 13, and a flat annular portion 23 similar to the annular portion 15 of the coupling member 13. The coupling member 21 also includes a portion 20 which serves the double function of constituting a flange to which the cone 5 is secured and a mass for loading the cone. While the mass 20 is shown as an integral part of the coupling member 21, it is

to be understood that it may be made in the form of a separate member adapted to be secured either to the coupling member or directly to the cone in the neighborhood of the coupling. The effect of loading the cone by the mass 20 is to introduce a sharp cut-off frequency which by proper evaluating of the values of the compliance of the coupling system and the mass of the loading member, may be placed either at a higher or lower frequency than the cut-off for the system shown in Fig. 3. In some types of acoustic apparatus it is very desirable to have a sharp cut-off at a desired frequency.

Fig. 6 illustrates a circuit which is the electrical equivalent of the apparatus of Fig. 5. The circuit includes an inductor 11, a resistor 12 and a capacitor 13 similar to the corresponding elements of Fig. 4. In addition the circuit includes an inductor 24 connected in series with the resistor 12. The inductor 24 represents the mechanical impedance of the mass 20. As shown in the circuit diagram the mechanical impedance of the mass 20 is in series with the mechanical impedance of the cone 5 which is represented by the resistor 12.

Fig. 7 illustrates a modification in which the compliance between the driving coil and the diaphragm is obtained by means of the connection between the coil form 6-a and the diaphragm 5. The additional loading is provided by the ring 20-a which provides a mass of the desired value. The mass ring may be located immediately adjacent the junction of the diaphragm and voice coil form, as shown at 20-a, or it may be spaced a small distance from the junction as indicated at 20-b by dotted lines.

Fig. 8 is a graph illustrating characteristics of the apparatus of Figs. 1, 3 and 5. Curve A of Fig. 8 is the sound pressure versus frequency characteristic of the apparatus of Fig. 1. When there is a compliant connection between the driving portion and the sound wave producing portion of the vibratile system, the response characteristic is changed to the curve shown at B. Curve B shows that the introduction of the compliant link or coupling reduces the high frequency response of the device. When the mass 20 is added to the diaphragm as shown, for example, in Fig. 5 the high frequency cut-off is made sharp as indicated by curves C and D. These curves illustrate how the cut-off can be controlled by varying the flexibility of the compliant coupling and the mass of the loading member.

Figs. 9 to 18 show various modified structures for introducing a compliant coupling between the voice coil driving system and the diaphragm of an electrodynamic loudspeaker, and corresponding electrical circuits. All of these constructions are modifications of the construction shown in Fig. 3. In Fig. 9 the compliant coupling is introduced into the end of the coil form 30 by providing one or more annular corrugations 31 in the end of the coil form adjacent its connection with the diaphragm 5. The degree of stiffness of the compliant coupling can be controlled by varying the depth and shape of the corrugations.

In Fig. 10 the compliant coupling between the driving portion and the sound reproducing portion of the vibratile system, is introduced into the system by annular corrugations 32 formed in the cone 33 adjacent its connection with the coil form 34. It is usually desirable to use this modification where the diaphragm is of the "morning glory" type. This construction is also

especially effective where a small, sharp-angle cone is used.

In the modification illustrated in Fig. 11 the compliance is distributed between the coil form and the diaphragm. The coil form 35 has one or more annular corrugations 36 formed therein at the end of the coil form adjacent its connection with the diaphragm. The diaphragm 37 also has one or more annular corrugations 38 located in the portion of the diaphragm immediately adjacent its connection with the coil form 35.

In the modification illustrated in Fig. 12 the compliant coupling between the diaphragm and the driving coil is the same as the compliant coupling in the modification illustrated in Fig. 9. In Fig. 12, however, the driving coil is divided into sections 40 and 41. These sections are separated from each other by a compliant coupling 42 formed in the coil form. The winding 40 comprises the high frequency winding of the voice coil system and the winding 41 comprises the low frequency section of the voice coil system. The high frequency response of the vibratile system as a whole, is increased by dividing the driving coil into high and low frequency sections and by using only the high frequency section for reproducing high frequencies. This arrangement is described in detail in the copending Ringel and Olson applications hereinbefore mentioned. The compliant coupling between the voice coil and the diaphragm 9 provides an additional control of the high frequency response.

In the modification illustrated in Fig. 13 the voice coil is divided into two sections 40 and 41 which are separated by a compliant coupling 42 in the voice coil form, in the same manner as in the modification illustrated in Fig. 12. The compliant coupling between the voice coil system and the diaphragm is inserted in the diaphragm 43 adjacent its connection with the coil form. As in previous modifications the compliance is formed by providing one or more annular corrugations 44 in the diaphragm.

In the modification shown in Fig. 14 the voice coil is divided into high frequency and low frequency sections 40 and 41 separated by a compliant coupling 42, similar to the arrangement shown in Figs. 11 and 12. The compliant coupling between the voice coil system and the diaphragm is shown at 45. It consists of a plurality of corrugations distributed over an elongated neck portion formed in the coil form 46 between the high frequency coil 40 and the diaphragm 47. In some instances it has been found desirable to distribute the compliance over an elongated portion of the coil form between the driving coil and the diaphragm.

Fig. 15 illustrates a modification in which the coil form has an elongated neck portion 50 between the voice coil 10 and the diaphragm 5. A compliant coupling 51 is inserted between the coil 10 and the neck portion 50. The elongated neck portion permits large amplitudes of movement of the diaphragm and coil form which is desirable for low frequency production.

Fig. 16 is the equivalent electrical circuit of the apparatus of Fig. 15. The inductance 11 corresponds to the mechanical impedance of coil 10. Condenser 52 corresponds to the compliance of the coupling 51. Inductance 53 corresponds to the mechanical impedance of the neck portion 50 which has an appreciable mass. Condenser 54 corresponds to the compliance of the junction 55 between the coil form and the diaphragm.

Fig. 17 illustrates a modification having the

elongated neck portion 50 of Fig. 15 and the double voice coil arrangement of Fig. 14. The same reference numerals are used to designate the same parts that are used in the apparatus of Figs. 14 and 15.

Fig. 18 represents the equivalent electrical circuit to the apparatus shown in Fig. 16. Inductances 56, 57 and 53 represent respectively the mechanical impedances of the elements 41, 40 and 50 of Fig. 17. Condensers 58, 52 and 54 represent the compliances 42, 51 and 55.

While the apparatus illustrated in Figs. 9 to 18 shows in all instances a plurality of annular corrugations for providing the necessary compliance, it is to be understood that various other means of introducing compliance into the system may be used. For example, the coil form and/or the diaphragm may be made much thinner at the locations now containing the annular corrugations. This will increase the flexibility of the coil form and/or the diaphragm at the necessary areas and thus introduce the desired compliance into the system. The desired compliance may also be obtained by perforating or slotting the coil form or the diaphragm. Such perforations or slots would preferably be made at the same parts of the coil form and the diaphragm where the annular corrugations are shown in Figs. 9 to 18. The perforations may be of any shape to provide the desired compliance. The slots may be formed annularly or longitudinally of the coil form or diaphragm, or in any other way which will produce the desired compliance between the driving portion and the sound wave producing portion of the vibratile system.

The compliance may also be formed by introducing sections of more flexible material than that of the coil form and diaphragm into the coil form or diaphragm at the portions thereof where the annular corrugations are shown in Figs. 8 to 13.

While I have shown an approved form of the invention and various modifications thereof, it is to be understood that various other modifications may be made thereto without departing from the spirit of the invention, and that the invention is not to be limited to the modifications shown and described hereinbefore but only by the scope of the appended claims.

What I claim is:

1. Acoustic apparatus comprising a conical diaphragm, a driving coil for said diaphragm, flexible means connecting said diaphragm with said driving coil, and means loading said diaphragm adjacent the part of said diaphragm to which said flexible means is connected.

2. Acoustic apparatus comprising a conical diaphragm, a voice coil for actuating said diaphragm, a coil form on which said voice coil is disposed, a flat annular flexible member extending from said voice coil form to the apex portion of said diaphragm and a thickened portion at the peripheral edge of said flat annular member for loading said diaphragm.

3. Acoustic apparatus comprising a frustum-shaped diaphragm, a voice coil for actuating said diaphragm, a cylindrical form on which said voice coil is disposed, and a metallic member extending between said form and the smaller base of said frustum-shaped diaphragm for connecting said diaphragm with said coil form, said metallic member having a portion secured to said coil form, a thickened portion secured to said diaphragm for loading said diaphragm, and a flat

flexible portion intermediate the first mentioned portions.

4. Acoustic apparatus comprising a diaphragm, a voice coil for actuating said diaphragm, a coil form on which said voice coil is disposed, said coil form having a portion connected with said diaphragm and a compliant coupling in said coil form interposed between said voice coil and said diaphragm and immediately adjacent the portion of said coil form connected with said diaphragm.

5. Acoustic apparatus comprising a conical diaphragm, a voice coil form secured to said diaphragm, a voice coil on said voice coil form, means providing a flexible portion in said voice coil form between said voice coil and the part of said form secured to said diaphragm, and means providing a flexible portion in said diaphragm immediately adjacent the portion of said diaphragm connected with said voice coil form.

6. Acoustic apparatus comprising a conical diaphragm, a voice coil form secured to the apex portion of said diaphragm, a voice coil disposed on said form, annular corrugations in said voice coil form, other annular corrugations in said diaphragm, the corrugations in said coil form being immediately adjacent the corrugations in said diaphragm.

7. Acoustic apparatus comprising a conical

diaphragm, a voice coil form secured to said diaphragm, compliant coupling means dividing said voice coil form into a plurality of sections, a voice coil winding disposed on each of said sections, and a compliant coupling in said voice coil form between the portion of said voice coil form connected with said diaphragm and the winding on said voice coil form nearest said diaphragm.

8. Acoustic apparatus comprising a conical diaphragm, a voice coil form secured to said diaphragm, compliant coupling means separating said voice coil form into a plurality of sections, a voice coil winding on each of said sections, said section adjacent said diaphragm including a neck portion disposed between the winding on said portion and said diaphragm, and a plurality of annular corrugations distributed over said neck portion for increasing the flexibility of said neck portion to control the high frequency response of said acoustic apparatus.

9. In a loudspeaker, a diaphragm, a driver, connecting means between said diaphragm and said driver whereby the diaphragm may be caused to vibrate, said connecting means including a resilient coupling adjacent to the driver, and an element having predetermined mass located between the coupling and the diaphragm.

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