

Sept. 16, 1941.

M. E. SWIFT

2,256,270

LOUD SPEAKER

Filed Jan. 29, 1940

2 Sheets-Sheet 1

Fig. 2.

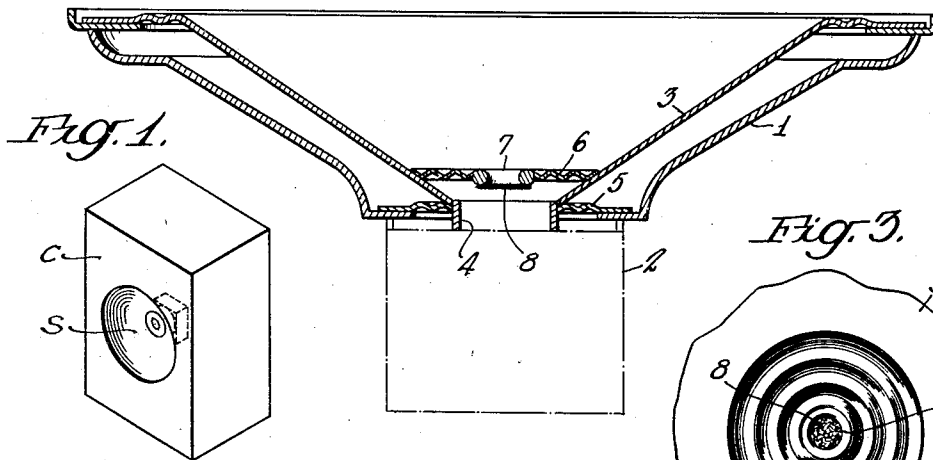


Fig. 3.

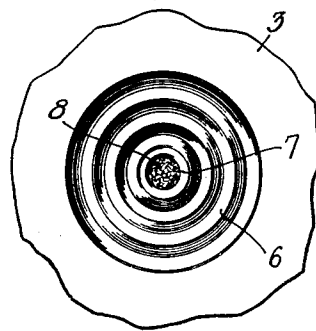


Fig. 8.

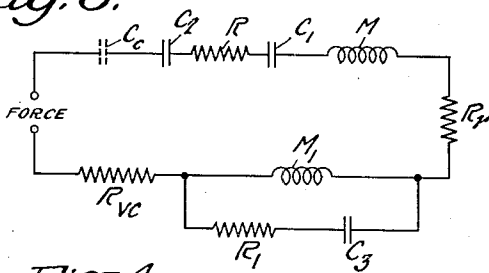


Fig. 4.

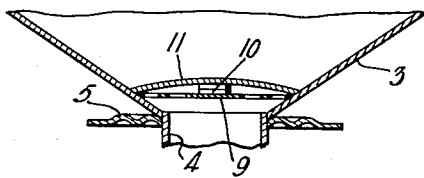


Fig. 5.

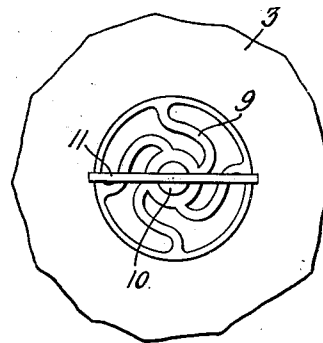


Fig. 7.

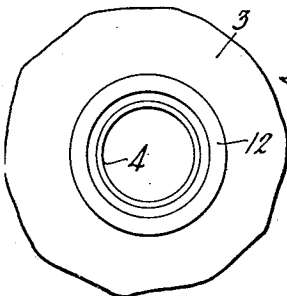
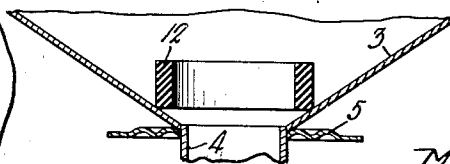


Fig. 6.



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Fig. 9.

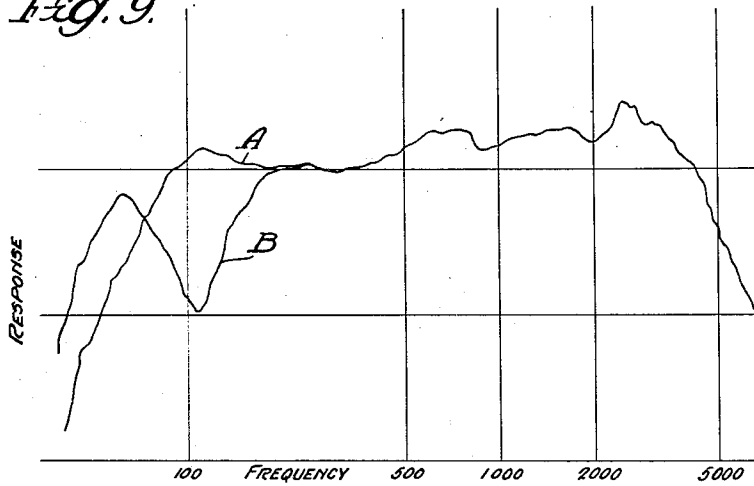


Fig. 10.

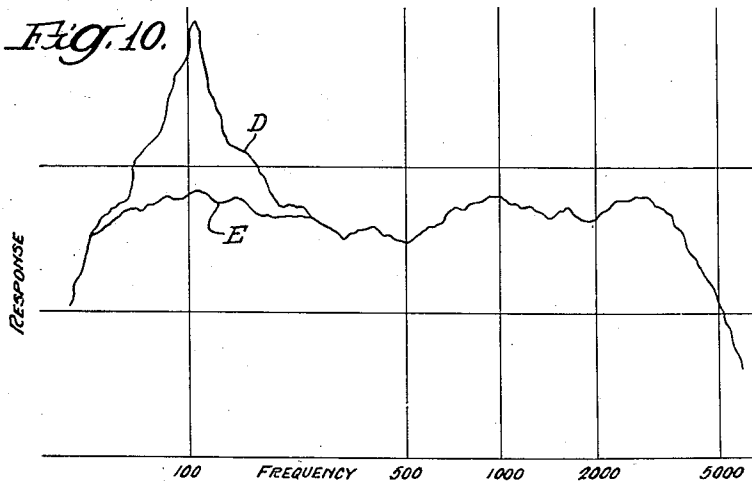
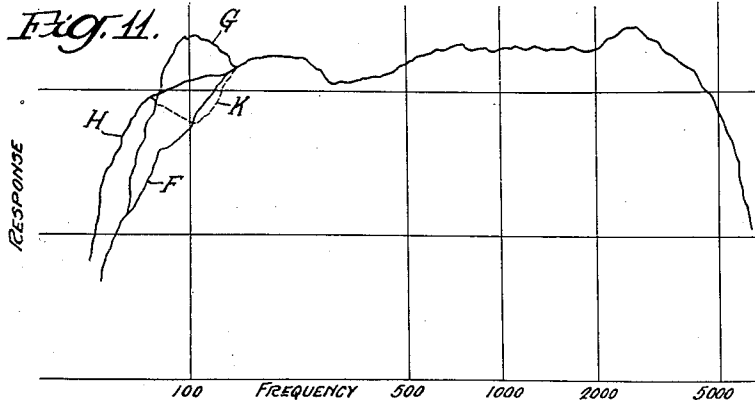


Fig. 11.



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UNITED STATES PATENT OFFICE

2,256,270

LOUD-SPEAKER

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Application January 29, 1940, Serial No. 316,268

7 Claims. (Cl. 181-31)

This invention relates to loud speakers of the electrodynamic, direct radiator type and more particularly to the vibratory diaphragms thereof. When a speaker of this type is used with a cabinet, baffle, or other partially closed structure, sound energy propagated from the speaker within a particular range of frequencies may be returned to it in such manner as to increase the intensity of the radiated sound. Such an effect is commonly known as cabinet or cavity resonance. For example, in a conventional automobile radio receiver installation utilizing a loud speaker mounted on the instrument panel of the automobile, this resonant effect reaches unusual proportions, and since the resonance usually occurs in the range of the lower voice frequencies, the desired uniform speaker output cannot be obtained. While careful cabinet design will reduce the resonance effects, in cases such as automobile installations the conditions for the elimination of resonances cannot be met in practice without a substantial increase in production costs. Under such circumstances, it becomes necessary to employ corrective devices to introduce losses which compensate for the resonance effects.

It is known also in the loud speaker art that the frequency response characteristic may be controlled over a moderate range by changes in construction and design. However, the range over which substantially uniform response can be obtained with small and medium size speakers is not sufficient for the desired present day high quality reception unless costly refinements are incorporated in the speaker. In particular, the low frequency response of speakers is generally deficient. It is known that for good speaker efficiency at high frequencies the vibrating diaphragm should be a light, stiff membrane having a large modulus of elasticity, and that for good efficiency at low frequencies the diaphragm should have considerable mass. These requirements are among the more important considerations which establish the range of uniform response of a speaker. With the above in mind, attempts have been made to extend the range of a speaker by providing multiple diaphragm and multiple voice coil speakers, but such devices are known to be unsuitable for use on small, inexpensive speakers.

Various acoustic devices have also been used in attempts to extend the range of good speaker response, but such devices are costly and generally too large for common use.

The principal object of the present invention

is to improve the frequency response characteristic of loud speakers by a simple, dependable, and inexpensive means which may be used on speakers of all sizes. This object is achieved in the present instance by providing a device which in one range of frequencies, such as the range of cavity resonance effects, serves as a loading device on the vibrating diaphragm, and which, in addition, in the range of the lower audio frequencies, becomes coupled to the speaker diaphragm so as to add mass to the same for the better reproduction of low frequency sounds. It will be understood that the degree to which each of these effects will be present may be controlled, as will be more fully described hereinafter.

Another object of the invention is to provide a simple device which may be used with conventional loud speakers to extend the frequency response thereof.

Still another object of this invention is to provide a simple and inexpensive means for diminishing cavity resonance effects in loud speaker installations.

A further object of the invention is to provide a device which will oppose and diminish the transient distortion effects which are characteristic of speaker systems in which cabinet resonance occurs.

The invention may be clearly understood by reference to the accompanying drawings, in which

Fig. 1 illustrates the loud speaker mounted in an enclosure which would give rise to cabinet resonance effects were it not for the present invention;

Fig. 2 is a sectional view of a loud speaker embodying one form of the invention;

Fig. 3 is a fragmentary face view of the device of Fig. 2;

Fig. 4 is a fragmentary sectional view of a loud speaker embodying a different form of the invention;

Fig. 5 is a face view of the same;

Fig. 6 is a fragmentary sectional view of a loud speaker embodying a further form of the invention;

Fig. 7 is a face view of the same;

Fig. 8 is an electrical diagram illustrating the invention by way of electrical analogs; and

Figs. 9 to 11 are explanatory curves.

The illustration of Fig. 1 shows the loud speakers within a cabinet or enclosure C which may modify the acoustic and mechanical properties of the speaker, as will be further described hereinafter.

In Figs. 2 and 3 there is shown a loud speaker embodying a form of the invention. The speaker includes a frame 1, pole piece structure 2, cone 3, moving coil 4, and a centering spider 5, all of which may be of standard construction. To this unit there is added a concentrically corrugated annular diaphragm 6 secured at its outer edge to the cone adjacent the apex thereof. This diaphragm may be formed from a variety of materials. For example, a cloth member impregnated and coated with synthetic rubber may be used. About the inner edge of the diaphragm a small mass 7 is distributed, as by puddling the rubber or other suitable material in the innermost corrugation. To close the center of the diaphragm a loosely woven felt dust cover 8 may be applied.

The invention may take various other forms, such as those of Figs. 4 to 7 to be described hereinafter. Since the principles and operation are the same in any instance, however, it is believed that a clear understanding of the invention will be facilitated by a discussion of the operation and characteristics with reference to the device of Figs. 2 and 3, before proceeding to the consideration of modified forms.

When any element such as a loud speaker diaphragm is suspended by means of a resilient material, such an element will have a natural resonance in some small frequency range, and when excited at a frequency in this range such element will vibrate with large amplitude and will absorb considerable energy from the exciting source. The frequency at which the resonance occurs, the degree of the resonance, and the breadth of the resonant frequency range, may be varied by altering the mass, compliance, and mechanical resistance of the element and its supporting members. Thus, in the case of the present construction the resonant range of the cone will be fixed by its mass and by the compliance of the centering spider and elements. As noted above, however, it is not convenient in commercial speaker manufacture to proportion the elements so that the resonant frequency of the speaker cone will be sufficiently low in the audio frequency range. Thus, the speaker cone resonance will often occur in the neighborhood of 150 cycles per second, and since the speaker response decreases rapidly below the region of resonance, this high resonant frequency is undesirable.

In accordance with the present invention, the frequency characteristics of the cone are varied by the addition of the auxiliary diaphragm whose resonant frequency range may be controlled by varying the mass and compliance thereof. Thus the diaphragm resonance may be made to occur at a frequency which may, for example, be a predetermined number of cycles above or below the speaker cone resonant frequency.

The results of adding a diaphragm or other member, according to the present invention, can best be understood by considering Figs. 8 to 11.

Fig. 8 shows an electrical circuit diagram comprising generally elements analogous to the speaker components in Figs. 2 to 4. In this circuit, voltage represents mechanical force, and current represents velocity. M is an inductance representing the mass of the speaker cone. C_1 and C_2 are capacitances representing the compliance of the flexible cone-supporting edge and the cone centering spider respectively. R is a resistance representing the internal mechanical friction of the speaker cone and its supports. Similarly, M_1 , C_3 , and R_1 represent respectively

the mass, compliance and resistance of the auxiliary diaphragm or member, and R_{vc} represents the equivalent mechanical resistance due to the electrical resistance of the voice coil circuit. R_r represents the radiation resistance of the speaker, which increases with frequency. It will be understood that the power delivered to R_r is a measure of the acoustic output of the speaker, and since this power is proportional to the square of the velocity times this resistance, the problem becomes one of securing a mechanical impedance across the input terminals which provides, throughout the frequency range of the system substantially uniform radiated power. In a usual speaker installation, M , C_1 , and C_2 will be resonant at about 100 cycles. M_1 , R_1 , and C_3 may readily be adjusted to resonate at some desired frequency.

The mechanical and acoustic properties of the system are modified to a greater or less extent by the cabinet or other mounting means employed. For example, if the speaker mounting shown in Fig. 1 takes the form of a small closed box, the compliance of the air volume within the same may be represented in Fig. 8 by an additional series capacity C_4 . Other forms of mounting that are more complicated acoustically would introduce other correspondingly more complex elements in Fig. 8 in the form of additional resonant and anti-resonant arms in the circuit. No attempt has been made to represent in Fig. 8 examples of these more complicated elements.

The curves of Figs. 9 to 11 illustrate the speaker response as follows:

Curve A (Fig. 9) is the frequency response curve of a typical small loud speaker such as is now used in small radio receivers. A slight resonance can be noted at slightly over 100 cycles. In the equivalent circuit M_1 , R_1 , C_3 , and C_4 are not present.

Curve B is the frequency response curve of the same loud speaker fitted with a loading diaphragm according to this invention which is resonant slightly above 100 cycles so that it serves as a good energy absorber at this frequency, this decreasing the amplitude of the speaker cone vibrations and also the speaker output. All of the elements in Fig. 8 except C_4 are present. The operation of this device comprising a cone and diaphragm may be described qualitatively as follows: When the cone is driven at high frequencies, there will be substantially no motion of the diaphragm mass due to the diaphragm compliance and the small amplitude of the cone vibrations. Thus, at the high frequencies the speaker will have its normal response. As the speaker approaches the resonant frequency of the diaphragm, the same will absorb energy from the cone, thus decreasing the amplitude of the cone vibration and consequently the acoustic output of the speaker. At still lower frequencies, below the resonant frequency of the diaphragm, the diaphragm will have such stiffness as to cause the diaphragm and mass to move as a unit with the speaker cone. This effectively adds mass to the moving system of the speaker, thereby lowering its resonant frequency and increasing the speaker efficiency so that the speaker response is increased in this region, as shown in curve B.

Considering Fig. 8, it will be understood that at the resonant frequency of M_1 and C_3 , the velocity in R_1 will be small; and that at lower frequencies M_1 will predominate, and in series with M , will lower the resonant frequency of M ,

C_1 , and C_2 , and effectively add mass to the system.

Referring now to Fig. 10, curve D, is the frequency response curve of the speaker noted in connection with curve A when the same is fixed in a baffle structure having a pronounced cavity resonance in the region of 100 cycles, and is representative of the usual speaker response when the speaker is mounted on the instrument panel of an automobile. This resonance is responsible for a pronounced "boomy" quality of the reproduced program.

Curve E is the frequency response of the same speaker but including the present invention positioned in the same baffle structure. It will be noted that the cavity resonance effect has been completely corrected and an overall uniform response has been obtained. In the equivalent circuit of Fig. 8, it may be considered that M_1 , C_3 and R_1 are so adjusted that they will compensate for the elements introduced by the cavity resonance.

In Fig. 11 there are shown curves of the speaker response under different operating conditions. Curve F is the response curve of the speaker alone without the present invention. Curve G is the speaker response when in a partially closed cabinet. Curve H is the response curve of the speaker including the present invention in the cabinet. It will be noted that the low frequency response is greatly improved and that the loading effect of the diaphragm, (represented by the dotted line K) is used to correct for the cabinet resonance effect to give a uniform response. This result may be obtained and is particularly applicable when the cabinet has a considerable volume as in a console mounting for home use. Under these circumstances, the equivalent circuit elements in Fig. 8 are such that C_1 , C_2 , M_1 , and M_2 resonate at the same frequency, but at lower frequencies M_1 predominates over C_3 so that M_1 again effectively adds mass to the moving system of the speaker. This effect may likewise be readily obtained on speakers positioned in small cabinets if the cabinets are not closed on the side to the rear of the speaker.

A comparison of the curves in Fig. 9 will show that the areas below curves A and B are essentially equal in the case where R_1 is small. Similarly in Fig. 11 the improvement in low frequency response indicated by the increased area below curve H, as compared to curve F, will equal the difference between the areas below curves G and F, again neglecting R_1 . Thus, a particular speaker in a certain enclosure will have a total power output indicated by the area beneath its response curve. Obviously the addition to the speaker of any absorption device can not increase this area but can only change the configuration of curve to present a more uniform response. This, however, will usually constitute an increase in the usable speaker output, since formerly undesired resonant responses heretofore discarded, such as those due to cabinets, may now be used for useful output by redistributing the energy represented by the area under the resonant peaks in the response curve so as to extend the low frequency response of the system.

In Figs. 4 and 5 there is illustrated another form of the invention applied to a speaker employing a standard inside type speaker centering spider 9 secured, as by glueing, to the speaker cone 3. These spiders are commonly made of "Armco" paper or of canvas or linen, impregnated with Bakelite or other suitable resinous

material. In accordance with the invention, a mass 10 is secured to the center of the spider. If it is desired to broaden the resonance of this unit or to dampen the vibrations thereof, a damping means may be added. In these figures a small piece of viscoloid or other material is indicated at 11 secured to the cone or spider at its ends and to the mass 10 at its middle. This damping material is preferably a substance having a large internal mechanical resistance per unit of mass. If desired, the spider may be impregnated with the damping material instead of adding a separate damping member.

Another embodiment of the invention is shown in Figs. 6 and 7. This comprises an annular ring 12 of sponge rubber or other suitable material having a rectangular cross-section as shown, secured at one edge of the speaker cone 3. The rubber may also be selected to have the desired mass, compliance, and mass to compliance ratio and, hence, will act in a manner essentially the same as the diaphragm of Figs. 2 and 3 vibrating as a unit only at the low frequencies.

One embodiment of the invention, as illustrated in Figs. 2 and 3, which has been used commercially comprised a speaker having a five and one-half inch diameter cone made in accordance with good commercial practice. The diaphragm 6 was made of airplane cloth impregnated and coated with a synthetic rubber material such as neoprene, to a total thickness of fourteen-thousandths of an inch, while the mass 7 was approximately .9 of a gram. Such a diaphragm was found to lower the speaker resonant frequency more than 15 cycles while causing a loss in the acoustic output of 17 decibels at the resonant frequency of the diaphragm, compensating for an increase in output of the same amount caused by a pronounced cavity resonance in an automobile installation. It will be understood that these values were selected to meet specific requirements in a particular installation where the elimination of cavity resonance was the most important consideration and are not to be considered as limiting the invention.

From the above description, it will be seen that the invention adds to a loud speaker a member which may readily be adjusted to have a desired ratio of mass to compliance and a natural resonance at a predetermined frequency, such that the combination of the member and the speaker will yield a more uniform speaker response over an extended frequency range. The device is extremely simple in both design and construction. The desired properties of the materials may be easily obtained in commercial production and, hence, the units are inexpensive and readily obtainable.

It will be understood, of course, that the invention may take other forms than those illustrated and its scope is to be defined only by the appended claims.

I claim:

1. Sound reproducing apparatus including, in combination, a diaphragm, means for resiliently mounting said diaphragm, means for vibrating said diaphragm, a flexible annular member secured at its outer peripheral edge to said diaphragm, and a mass supported on the inner edge of said member.

2. Sound reproducing apparatus including, in combination, a frame, a diaphragm resiliently mounted on said frame, means for vibrating said diaphragm, and an annular diaphragm secured

at one peripheral edge to said first diaphragm and unsupported at its other edge, said annular diaphragm having a period of vibration differing from the natural period of said diaphragm.

3. Sound reproducing apparatus including, in combination, a frame, a diaphragm resiliently mounted on said frame, means for vibrating said diaphragm, and an annular diaphragm secured at one peripheral edge to said first diaphragm and unsupported at its other edge, said annular diaphragm having a period of vibration differing from the natural period of said diaphragm, said annular diaphragm being weighted adjacent its free edge.

4. In a sound reproducing device, a loud speaker having a diaphragm, a cavernous support for said speaker having an inherent natural resonance at a certain frequency within the frequency range of the speaker, tending deleteriously to affect the frequency response of said speaker, and vibratory means having both compliance and mass attached to said diaphragm and having a resonant frequency substantially coincident with the resonant frequency of said cavernous support, thereby to absorb energy from said diaphragm when the latter vibrates at the resonant frequency of said cavernous support, whereby the deleterious effect of the cavernous support resonance is substantially neutralized.

5. In a sound reproducing device, a loud speaker having a diaphragm, a cavernous support for said speaker having an inherent natural resonance at a certain frequency within the frequency range of the speaker, tending deleteriously to affect the frequency response of said speaker, and vibratory means having both compliance and mass attached to said diaphragm and having a resonant frequency substantially coincident with the resonant frequency of said cavernous support, thereby to absorb energy from said diaphragm when the latter vibrates at the resonant frequency of said cavernous support, said vibratory means having a predetermined mass-to-compliance ratio such that it adds mass to said diaphragm at lower frequencies, whereby the

deleterious effect of the cavernous support resonance is substantially neutralized and the low frequency response of said speaker is extended.

6. In a sound reproducing device, a loud speaker having a diaphragm, a cavernous support for said speaker having an inherent natural resonance at a certain frequency within the frequency range of the speaker, tending deleteriously to affect the frequency response of said speaker, a compliant member attached to said diaphragm, and a mass carried by said member, said compliant member and said mass in combination having a resonant frequency substantially coincident with the resonant frequency of said cavernous support, thereby to absorb energy from said diaphragm when the latter vibrates at the resonant frequency of said cavernous support, said compliance and mass combination having a predetermined mass-to-compliance ratio such that it adds mass to said diaphragm at lower frequencies, whereby the deleterious effect of the cavernous support resonance is substantially neutralized and the low frequency response of said speaker is extended.

7. In a sound reproducing device, a loud speaker having a diaphragm, a cavernous support for said speaker having an inherent natural resonance at a certain frequency within the frequency range of the speaker, tending deleteriously to affect the frequency response of said speaker, and a member having both compliance and mass attached to said diaphragm and having a resonant frequency substantially coincident with the resonant frequency of said cavernous support, thereby to absorb energy from said diaphragm when the latter vibrates at the resonant frequency of said cavernous support, said member having a predetermined mass-to-compliance ratio such that it adds mass to said diaphragm at lower frequencies, whereby the deleterious effect of the cavernous support resonance is substantially neutralized and the low frequency response of said speaker is extended.

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