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E. C. NILSON
ACOUSTIC DIAPHRAGM

1,748,990

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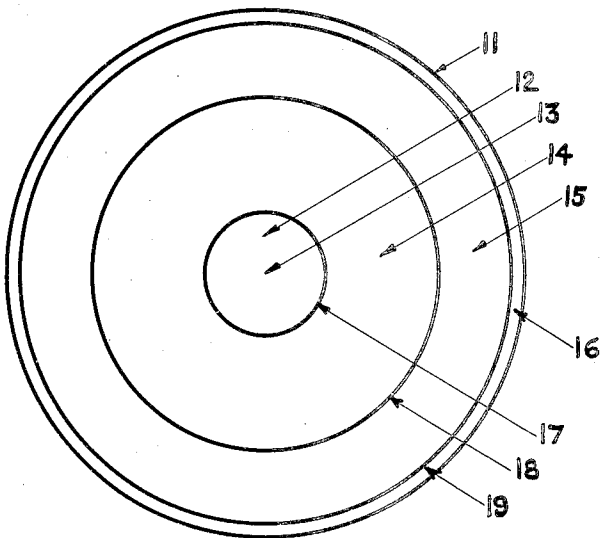


FIG. 1

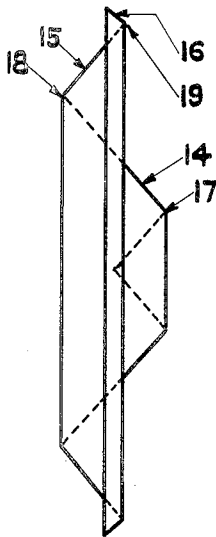


FIG. 2

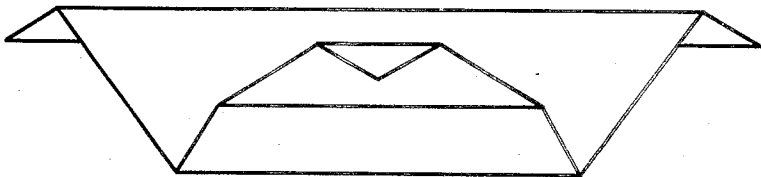


FIG. 3

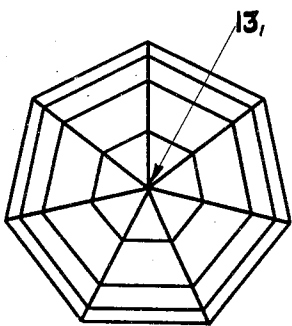


FIG. 4

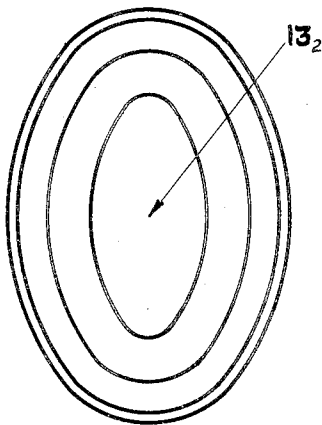


FIG. 5

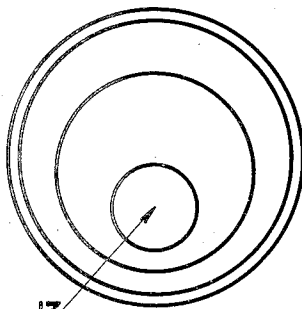


FIG. 6

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ACOUSTIC DIAPHRAGM

Application filed December 16, 1927. Serial No. 240,596.

This invention relates to diaphragms of loud speakers of the type known in the art as cone speakers. Its primary object is to combine the advantages of the free edge cone and the fixed edge cone and to eliminate some of the faults inherent in each of these types.

A further object of this invention is to devise a diaphragm having a plurality of aperiodic sections of differing acoustical characteristics whereby blasting at any particular sound frequency is eliminated.

A further object is to devise a diaphragm which is unconfined in its range and which is responsive to the highest notes as well as to the very lowest notes thereby covering the entire range of audibility.

A further object is to devise a diaphragm which has its center of inertia approximately at its point of support thereby making the driving force more effective at all volumes of received signals and especially feeble signals.

A further object is to devise a diaphragm with a plurality of sections each of which is most sensitive to a range of sounds between certain limiting frequencies.

Another object is to devise effective damping means for each of the several sections of which the diaphragm is composed.

Another object is to devise a diaphragm which is more rigid than either a free edge cone or a fixed edge cone of the same size and material.

Another object is to devise a diaphragm which has light weight but which is rigid enough over its entire surface to retain its shape when supported at a single point even when made in enormous sizes.

A further object is to devise a diaphragm which is ornamental and decorative and well balanced from an artistic viewpoint.

Further objects and advantages will be readily apparent to those skilled in the art.

Great difficulty has been encountered in attempting to produce a loud speaker of simple construction which will give faithful reproduction over the entire range of audibility. Cone speakers have overcome the main fault of speakers of the horn type, eliminating constriction of the sound waves and interfering echoes. At the present develop-

ment of the art, however, cone speakers have not been perfected to the extent that they will give reproduction without distortion over the entire audible range. Due to the fact that every vibrating diaphragm has its own period of mechanical resonance, sounds of a certain frequency are more readily sustained than sounds of other frequencies and this gives rise to distortion. One method of overcoming this objection is to use a diaphragm which has a natural resonance period outside the audible range. When such a diaphragm is used, other disadvantages appear which are even more objectionable than distortion due to resonance. For example, when a diaphragm is used which has a resonant point above the upper limit of audibility, volume of sound is sacrificed on account of the small size of such a diaphragm. On the other hand, a diaphragm which is so large that its natural resonance lies below the musical scale is too sluggish to respond to the higher notes of the scale unless an unduly strong operating force is applied to it.

This invention overcomes these disadvantages in a manner which will be hereinafter disclosed.

In order that the principles of this invention may be fully understood, attention is called to accompanying drawings in which:

Fig. 1 is a plan view of a diaphragm constructed in accordance with this invention.

Fig. 2 is a side view of the diaphragm shown in Fig. 1.

Fig. 3 is a cross section of a modification.

Fig. 4 is a modification having pyramidal sections.

Fig. 5 is a modification showing the invention applied to a diaphragm of oval or elliptical shape.

Fig. 6 is a modification showing the invention applied to an eccentric diaphragm.

In Fig. 1 a diaphragm 11 is shown having a central cone 12 with apex 13 and circumference 17. Adjacent cone 12 is a truncated cone 14, the smaller circumference 17 of which coincides with the circumference of cone 12. The outer circumference 18 of truncated cone 14 coincides with the smaller circumference of truncated cone 15 and in a like

manner the larger circumference 19 of the truncated cone 15 is coincident with the smaller circumference of the truncated cone 16. If desired, more sections, each comprising a truncated cone, may be added to those shown in the illustration. Under some conditions it may also be desirable to dispense with some of the sections, so that there may be as few as two sections comprising a central cone and a surrounding truncated cone. The dimensions of the several sections may be determined from several standpoints and I do not wish to be limited to any specific dimensions or proportions except as defined in the appended claims. Where the acoustical characteristics of the several sections are to be the deciding factors, more sections or fewer sections may be employed, each section being designed to cover its own acoustical range, regardless of the area of the other sections. The different sections may all have the same slope or different slopes as conditions may warrant.

In the particular embodiments illustrated, the dimensions and slope of the several sections are so chosen that the center of gravity and the center of inertia of the diaphragm is approximately at the apex of the central cone 12. It is at this point that the driving force is applied. It is well known that a force applied at the center of inertia of any mass is far more effective than the same force applied at any other point and for this reason the diaphragm illustrated will be more responsive to forces derived from feeble currents.

Such a construction allows the diaphragm to be supported at any angle without detracting from its efficiency. This feature is important where the diaphragm is large and is suspended at an angle to a wall or other background.

In constructing the diaphragm so that its center of mass occurs at the driving point, sections lying proximate the driving point may be of any desired dimensions, and preferably of such dimensions that they most faithfully reproduce sounds within certain frequency ranges and the outermost section or sections may then be used to balance the diaphragm. The central section 12, for example, may be of such size and mass to respond most faithfully to the highest range of audible sounds, section 14 to an intermediate range, and sections 15 and 16 to the lowest range and also to balance the diaphragm. It should be remembered, however, that the central section 12 and the other interior sections vibrate in unison with external sections for certain frequency ranges, as hereinafter described, and this should be taken into consideration in selecting the dimensions of these sections. If desired, these sections may be selected in respect to their volume response or any other acoustic characteristic instead of to

frequency response. After the dimensions of the internal section or sections have been fixed, the exterior section or sections of the diaphragm may then be used to balance the diaphragm so that its center of mass occurs approximately at the apex of the central section, calculating the dimensions of such external section or sections by means of the formula:

$$Q = M_1 R_1 + M_2 R_2 + M_3 R_3 \dots M_x R_x \quad 75$$

Where: Q is the statical moment about an axis passing through the apex of the central section and parallel to the plane of the base of the section.

$M_1, M_2, M_3 \dots M_x$ are the masses respectively of the several sections which compose the diaphragm.

$R_1, R_2, R_3 \dots R_x$ are the perpendicular distances of the center of gravity of the sections whose masses are $M_1, M_2, M_3 \dots M_x$ respectively, from the axis.

Since the statical moment about an axis passing through the center of mass of the diaphragm is equal to zero and since $M_1 R_1$ and $M_2 R_2$ may be predetermined and therefore of known value, the equation under these conditions becomes:

$$M_3 R_3 \dots M_x R_x = -M_1 R_1 - M_2 R_2 \quad 95$$

and where there are but three sections the equation becomes:

$$M_3 R_3 = -M_1 R_1 - M_2 R_2$$

The right hand side of this equation is of known value and any values of M_3 and R_3 which satisfy the equation will determine the dimensions of the outer section which will balance the entire diaphragm so that its center of mass occurs at the apex of the central section, at which point the driving force is applied. It will be understood that the mass M_3 will be different for the different materials of which the section may be made and the distance R_3 will be different for different slopes of the section so it is apparent that there are a number of solutions for the equation.

If desired, the outer section may also be determined by the cut and try method, that is, by making it larger or smaller until the diaphragm becomes balanced at the apex of the central section.

The invention is not limited to a diaphragm having its center of inertia at its point of support, however, and a diaphragm made in accordance with the invention from an acoustical viewpoint may have its center of inertia outside the point of support.

An explanation will now be given of the operation of the invention.

It will be apparent that the different sections forming the diaphragm may vibrate either individually or collectively in response to different driving forces. Cone 12, for ex-

ample, will respond to the higher notes or sounds because of its relatively small size. There will be little or no resonance in cone 12 since it is highly damped by the adjacent section 14.

Sounds next lower in the audible range will be reproduced by cone 12 and section 14 vibrating in unison. Resonant vibrations in this range of sounds are also absent by reason of the damping afforded by the adjacent section 15.

Still lower sounds will vibrate cone 12, section 14 and section 15 all in unison. Damping is provided for these sections by the section 16.

Sounds at the extreme lower end of audible range will vibrate the diaphragm as a whole and all sections will be in vibration for such sounds. Resonance is not important at this stage since the mass of the diaphragm prevents sustaining such resonance.

Since the several sections of the diaphragm are adapted to vibrate independently to the extent indicated, each section will be damped by an adjacent section which may not be vibrating at the same frequency. Damping is extremely effective under such circumstances and the entire absence of resonance in diaphragms of this type seems to indicate that the damping thus afforded is substantially instantaneous in its result. The damping effect provided by the exercise of this invention is in this manner an active force as distinguished from the passive force applied in certain other damping arrangements.

It will be obvious that such a construction will produce a diaphragm in which more frequencies are reproduced by plunger action of the diaphragm, as distinguished from transverse vibratory waves in the surface of the diaphragm. The small central section will act as a plunger type diaphragm on the higher frequencies, while the larger surfaces act as a plunger in reproducing the lower frequencies. By the automatic allocation of sounds in this manner to surfaces of different areas, there is a tendency for the amplitude of vibration to remain more nearly constant for all of the frequencies provided for in the design of the diaphragm.

In speakers of previous design it was desirable to use a large diaphragm so that low frequencies might be reproduced without too great a movement of the diaphragm. With such a diaphragm, however, the higher frequencies were distorted because the diaphragm prevented plunger action at these frequencies. On the other hand, when a smaller diaphragm is used so that the higher frequencies are more faithfully reproduced, the lower frequencies cause such a large amplitude of vibration that the pole pieces of the electro-magnetic unit are frequently struck by the diaphragm, thereby setting up harsh metallic noises. In the dynamic, or

moving coil, type of speaker the metallic noises are eliminated, but there is a detrimental effect on the flexibility and elasticity of the delicate coil supporting spider, thereby destroying its effectiveness and occasionally causing the arms of the support to break because of mechanical fatigue. Such disadvantages are obviously eliminated by the use of a diaphragm in which high frequencies are reproduced by a small area and the low frequencies by a large area, both having substantially the same relatively small amplitude of vibration.

Another important feature of this invention is also due to the individuality of the several sections and that is the automatic allocation of sounds of different intensities. Feeble forces which are too weak to vibrate the whole mass of the diaphragm will vibrate cone 12 alone and the sound will be heard as if a small speaker having a cone of this size were being used. As the intensity of the signals increases, more and more of the sections will come into play and signals which are loud will make use of the whole diaphragm.

Since feeble forces act upon a relatively small surface and strong forces vibrate a relatively large surface, the amplitude of vibration at the driving point will tend to remain more nearly constant over the entire volume range thereby giving rise to extremely important advantages.

Thus, in a diaphragm constructed in accordance with the present invention, there is a double allocation of the sound emitted from the diaphragm, one determined by the intensity of the sound and the other determined by its frequency, both allocations having a beneficial effect on the performance of the reproducer and increase the amplitude of vibration under conditions which would otherwise cause the amplitude of vibration to be too small and decrease it when it would otherwise be too great.

Ridges 17, 18 and 19 formed at the junctions of the several sections make the structure very rigid and diaphragms may be made in enormous sizes without requiring further support or reinforcement. This construction does away with the bulky and awkward frame-work required on previous types of cone speakers of large size. A diaphragm three feet in diameter is very rigid and retains its shape in any position when constructed according to this invention and no further reinforcement of any kind is needed. Diaphragms of greater diameter than three feet are also self-supporting. Smaller diaphragms made in accordance with this invention are extremely rugged in comparison with those of previous design.

Another feature of the diaphragm of this invention is that the outer sections serve as a baffle for sounds emanating from the inner

sections. Sections 14, 15, and 16 constitute a baffle surface for section 12; sections 15 and 16 serve as a baffle for sections 12 and 14; and so on, the baffling surface becoming relatively smaller as the area of the vibrating part of the diaphragm becomes larger. Thus, a baffle of large area is provided for feeble responses, under which condition a large baffle is more desirable and more effective, while a baffle of relatively smaller area is provided for the louder sounds, where the need of a baffle is less important.

Fig. 3 illustrates a diaphragm of somewhat different appearance. It is readily seen that an infinite number of shapes and designs may be made without departing from the scope of this invention. The dimensions and slopes, either one or both, may be varied giving rise to a wide range of patterns which are pleasing to the eye as well as to the ear.

Fig. 4 illustrates the invention as applied to a diaphragm having pyramidal sections. What has been explained in regard to a diaphragm composed of conical sections applies equally well to the pyramidal diaphragm.

Various kinds of conical sections may be employed and the invention is not limited to right circular cones. Elliptical cones, as shown in Fig. 5, or oblique cones, as shown in Fig. 6 are examples of some other cones which may be used.

Fig. 5 illustrates a diaphragm constructed in accordance with this invention having elliptical or oval shape. Such a diaphragm has the same advantages over the present oval cones as the circular cone described hereinbefore has over the simple cone of circular shape.

Fig. 6 illustrates the invention applied to a diaphragm having an eccentric apex.

Many other embodiments of this invention will be apparent to those skilled in the art without departing from the spirit of this invention as defined in the appended claims.

I claim:

1. In a sound amplifying device, a diaphragm, said diaphragm comprising a cone and a truncated cone surrounding said cone, the lesser circumference of said truncated cone and the circumference of said cone being coincident, the statical moment of said diaphragm about an axis passing through the apex of said cone and perpendicular to the axis of said cone being approximately zero.

2. In a sound amplifying device, a diaphragm, said diaphragm being composed of a plurality of sections, said sections comprising a cone and a plurality of truncated cones, each of said sections adjoining an adjacent section along a common circumference, the statical moment of said diaphragm about an axis passing through the apex of said cone and perpendicular to the axis of said cone being approximately zero.

3. In a sound amplifying device, a dia-

phragm, said diaphragm comprising a cone and a truncated cone surrounding said cone, the lesser circumference of said truncated cone and the circumference of said cone being coincident, the center of inertia of said diaphragm being located approximately at the apex of said cone.

4. In a sound amplifying device, a diaphragm, said diaphragm being composed of a plurality of sections, said sections comprising a cone and a plurality of truncated cones, each of said sections adjoining an adjacent section along a common circumference, the center of inertia of said diaphragm being located approximately at the apex of said cone.

5. In a sound amplifying device, a diaphragm, said diaphragm comprising a cone and a truncated cone surrounding said cone, the lesser circumference of said truncated cone and the circumference of said cone being coincident, the center of mass of said diaphragm being located approximately at the apex of said cone.

6. In a sound amplifying device, a diaphragm, said diaphragm being composed of a plurality of sections, said sections comprising a cone and a plurality of truncated cones, each of said sections adjoining an adjacent section along a common circumference, the center of mass of said diaphragm being located approximately at the apex of said cone.

7. In a sound amplifying device, a diaphragm, said diaphragm being composed of a plurality of sections, said sections comprising a cone and a plurality of truncated cones, each of said sections adjoining an adjacent section along a common circumference, said sections being individually designed to have predetermined acoustic characteristics.

8. In a sound amplifying device, a diaphragm, said diaphragm comprising a cone and a truncated cone surrounding said cone, the lesser circumference of said truncated cone and the circumference of said cone being coincident, the statical moment of said diaphragm about an axis passing through the apex of said cone and parallel to the base of said cone being approximately zero, said cone and truncated cone being individually designed to have predetermined acoustic characteristics.

9. In a sound amplifying device, a diaphragm, said diaphragm being composed of a plurality of sections, said sections comprising a cone and a plurality of truncated cones, each of said sections adjoining an adjacent section along a common circumference, the center of inertia of said diaphragm being located approximately at the apex of said cone and said sections being individually designed to have predetermined acoustic characteristics.

10. In a sound amplifying device, a dia-

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